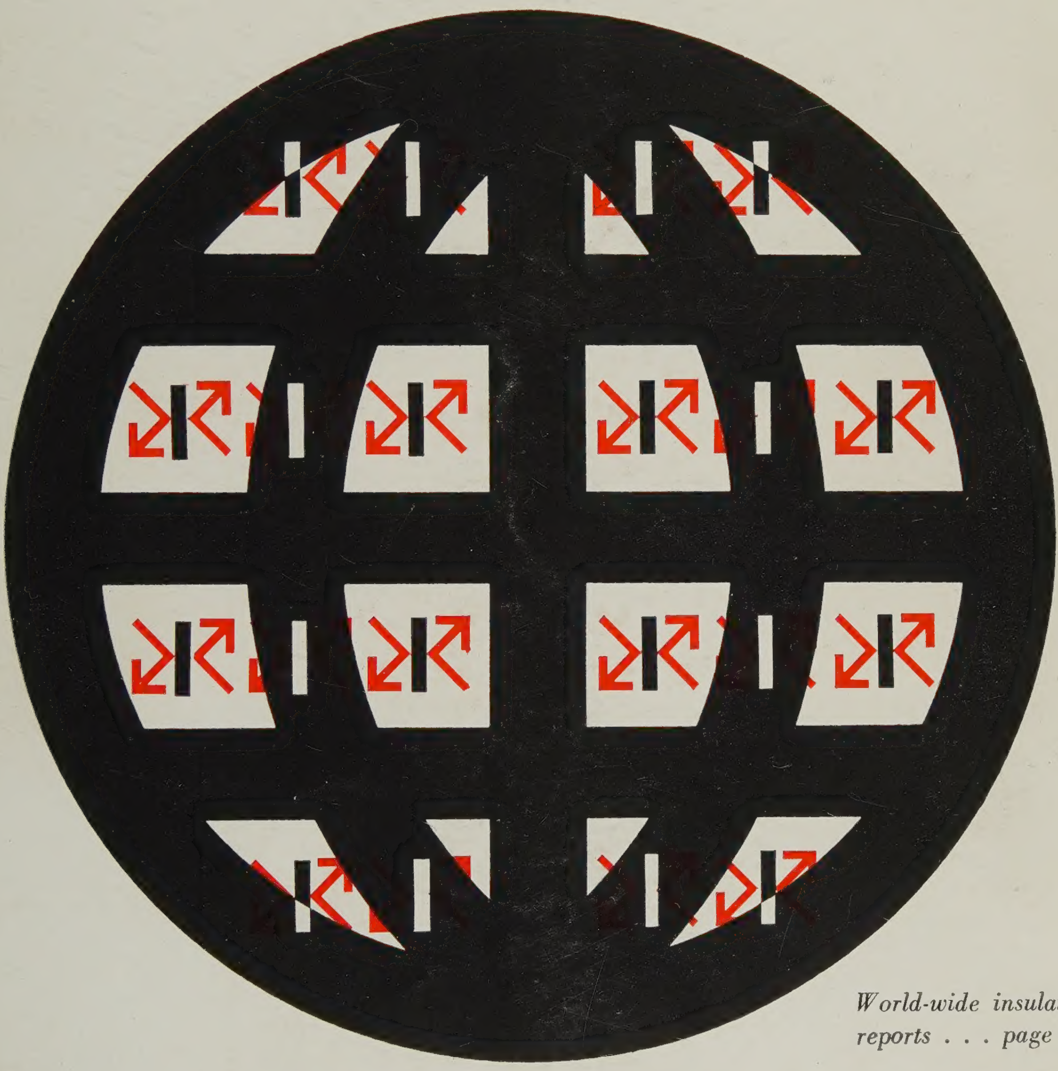
December 1960

Insulation



World-wide insulation reports . . . page 21

In this issue:


TEFLON* FILMS
CLASS H INSULATING TAPES
TEFLON* TUBING
SILICONE RU
COIL WRAPPI
INSULATING COMPOUNDS
2-IN-1 ELECTRICAL TAPES

rint Ins. 1 on Reader Service Card

Inmanco®...INSULATIONS START WITH TOP QUALITY MATERIALS EXCLUSIVELY!

Why does INMANCO believe so strongly in using only nationally recognized brands of materials?

The reason is simple. When you purchase an electrical insulating part, you buy two things—fabricating technique and material. No matter how professional the workmanship in the part, it is still the material itself which must measure up to the mechanical and electrical specifications of the application.

Consequently, all of the more than 1000 types and sizes of insulating materials used in INMANCO products are *nationally recognized brands* which have built a reputation for consistent quality.

This quality, enhanced by INMANCO's careful production techniques, is passed on to you in the form of fine electrical insulating products. Try them on your next job.

See Us at Booth No. 96, National Conference on the Application of Electrical Insulation

DU PONT MYLAR® POLYESTER FILM
MACALLEN MICA
H&V Groton®
NATIONAL VULCANIZED FIBRE
PHENOLITE® Laminated PLASTIC
PERMACEL
MANNING PAPERS
HAYSITE
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CONOLITE
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Made by Inmanco® DIVISION

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Insulation

For the Electrical and Electronic Industries

Lake Publishing Corporation, 311 East Park Avenue, Libertyville, Illinois, December 1960

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Advertising Sales Offices: See page 172.

From the Editor

Opinions and Rambling Thoughts

For Hi-Fi Addicts

From Ling-Altec Electronics Inc. in California comes word that batteries of 15-foot loudspeakers may soon be warning ships as far as five miles out to sea of hidden dangers to

navigation—both fog tone signals and spoken messages can be broadcast. We have a friend down the street who feels that hi-fi listening quality is in direct proportion to sound volume . . . here's hoping he doesn't read about these loudspeakers.

World-Wide Insulation Report

Another of *Insulation's* ambitious editorial programs, a world-wide insulation report, appears in this issue. Insulation experts from many countries have prepared articles on a variety of interesting subjects for this issue. Be sure to read all these excellent articles—they will give you a picture of insulation progress throughout the world.

Conference Section

The yellow insert sheet in this issue marks the beginning of a special section devoted entirely to the 3rd National Conference on the Application of Electrical Insulation being held December 5-8 at the Conrad Hilton Hotel in Chicago.

The conference section includes complete program information—meeting times, locations, and subjects for all sessions and functions. A plan of the third floor where all technical sessions will be held and a plan of the exhibition hall are included. Details on the Golden Omega award presentation to Dr. Mervin Kelly and the Unity of Action Banquet are provided. There is also information on points of interest in Chicago, highlights of the conference, and a report on the marketers' meeting. Plans for the AIEE luncheon and NEMA dinner are also covered. Another feature shows the committee workers who contributed so much to the success of the conference. In addition, there is a complete listing of all exhibitors with products to be featured. In this connection, be sure to visit *Insulation* in booth No. 48. We'd like the opportunity to greet new and old friends.

As you can see, this section is a complete guide to every event at the conference. Those attending the meeting will find it convenient to keep this issue with them at all times for reference purposes. Extra copies of *Insulation* will be available without charge at the conference.

A Record Issue and Year

This is a record-breaking issue of *Insulation*—it is bigger than any previous issue in number of pages and advertising volume. It also marks the end of our most successful year which was marked by a very healthy increase over 1959. Since its inception, *Insulation* has consistently broken records . . . and we'll be upset if more aren't broken next year. There are reasons beyond the magazine staff which account for this growth—first, the industry is growing and maturing as evidenced by the increasingly successful electrical insulation conference. Second, the readers find *Insulation* interesting and thus make it an effective advertising medium. Third, the insulation suppliers realize this and use advertising in *Insulation* on an increasing scale to reach the insulation users. Thus, our sincere thanks to the readers and advertisers for our growth.

Merry and Fruitful

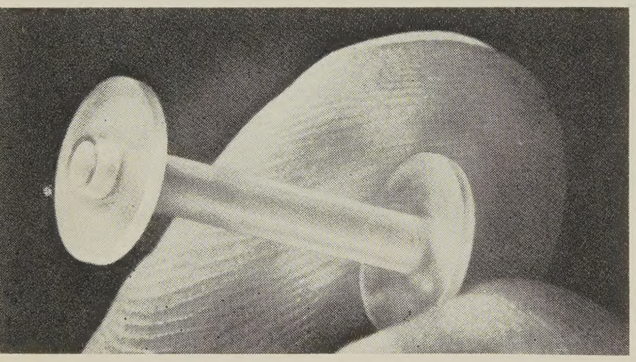
The staff of *Insulation* wishes every reader a very merry and thankful Christmas and a fruitful New Year filled with hope, success, and peace.

Resistor Compositions with Varied Resistance Values

Du Pont has announced new resistor compositions available in three resistance values (500, 3500, and 10,000 ohms per square per mil thick film) which can be blended to obtain intermediate values. Applied to ceramic dielectric bases by ordinary dip, brush, or stencil screen techniques, the composition is fired to obtain a durable surface. Miniaturized circuitry applications are expected. Resistance values reportedly show excellent stability under varying conditions of humidity, temperature, overload, and voltage. See the *New Products* section for more details.

Tiny Polycarbonate Machined Coil Form

A coil form only 0.725-inch long with 0.325-inch diameter flanges of 0.100-inch thickness is one of the tiniest plastic electrical components ever machined on a production line basis with automatic lathe equipment. Machined from ½-inch rod by Grimes Mfg. Co., it replaces a



machined metal form which had to be coated for electrical insulation and corrosion resistance purposes. The component is used in a solenoid safety switch on a warning light circuit for jet aircraft. Polycarbonate resin produced by Mobay Products Co. is used for the extruded rod stock.

Flame and Heat Resistant Coatings for Plastics

Continental-Diamond Fibre Corp. has announced successful experiments demonstrating that a group of flame and heat resistant coatings can be bonded to and are compatible with many grades of plastic sheets, tubes, and molded shapes. The air drying coatings can be applied by ordinary brush and spray techniques. More information in *New Products* section.

650,000 Volt Gas-Filled Capacitors

Sulfur hexafluoride filled capacitors, rated 650 kv, reported to be the highest voltage gas-filled capacitors ever built for outdoor use have recently been installed by General Electric. The three units, weighing 4.5 tons each and measuring 19 feet in height, have been designed for operating voltages as high as 750 kv and will withstand lightning surges up to 2,050 kv.

FEP Film Cementable With Common Adhesive

Another new product development of Du Pont is a "Teflon" FEP-fluorocarbon film, one side of which is cementable with common adhesives. Previously, the only way to obtain an adhesive receptive surface was by treatment with alkali metals in organic media. The new cementable type of film is being offered in developmental quantities at a premium over the standard film. It is expected to be used in pressure-sensitive tapes and for wire and cable to provide a printable or "pottable" surface, as well as other electrical applications.

Statistical Life-Testing Procedures Robust?

The National Bureau of Standards has been evaluating the robustness of acceptance sampling procedures used in life testing experiments. Procedures which can be used effectively when some of the underlying mathematical assumptions are not satisfied are termed robust. The study investigated the consequences of applying acceptance sampling procedures which assume an exponential failure law when actually the failure law is the Weibull distribution. It was found that these widely used statistical techniques are very sensitive to departures from initial assumptions.

Business Conditions Ahead

Some industry pundits are guardedly pointing to a quickening pace in some business areas to substantiate opinions that business isn't nearly as bad as some would have us believe. However, the attitude of most self-styled experts leans to the pessimistic side for the immediate future and very few of them will venture to define the present "adjustment" period . . . it seems that after their wrong appraisals of a few years ago, they are not inclined to stick their necks out again. As a result of numerous discussions with businessmen throughout the country, *Insulation's* editors think that business conditions will be much better . . . very soon. Part of the reason why a full-fledged recession did not and will not develop is that company officers made necessary cut-backs and increased marketing efforts at the first signs of a downturn earlier in the year—thus the "too late", more drastic cuts were avoided and any spiralling effect was blunted and stopped dead.

Insulation Forum

This regular monthly feature is built around a timely question concerning the electrical insulation field. Your suggestions for future questions and participation are invited. This month's question is:

What improvements in existing electrical/electronic insulating materials or what new material developments would you like to see made in the near future?

V. E. Culler

Research Associate, Physics, Industrial Reactor Laboratories, Corning Glass Works, Plainsboro, N.Y.

"A knowledge of the effects of high energy radiation on insulating materials has become extremely desirable, both from the standpoint of insulation applications and from the standpoint of pure science. As part of a general study of radiation effects on glasses and glass-ceramics, we are studying electrical resistivities of glasses under gamma-radiation.

"The measurement technique is made complex by ionization of the air surrounding the samples, which literally creates an ambient that is an electrical conductor. Imagine trying to measure the resistance of a hundred-ohm resistor imbedded in copper! We have to take special care to prevent air paths or short circuits from bridging a sample.

"Samples can be shaped to minimize or even eliminate such paths. For instance, a closed cylindrical shell can be used. However, there must be leads connecting the sample to measuring equipment, and the equipment must be in an area free of radiation. Leakage paths between leads cannot be permitted.

"Ideally, the leads could be immersed in a liquid insulator and led back through a radiation shielding wall to the measuring equipment. In actual practice we have been unable to find liquids of sufficiently high electrical resistivity (about 10^{17} ohm/cm) to do this. The use of wax such as ceresin is inconvenient since concealed air paths show up as short circuits only after irradiation has started. Liquid insulators could not have such paths.

"Thus, in the near future, I would like very much to see even sample amounts of liquid insulators that exhibit electrical resistivities three to four decades higher than those presently available. I would prefer that these liquids be stable under irradiation, but this is not a necessity."

John A. Strom

Senior Member, Technical Staff, Radio Corp. of America, Burlington, Mass.

"The past decade has seen great developments by industry. Particularly impressive is the amount of research applied to new products and applications.

"We in the electronics industry are always waiting, ready to apply to our products the latest technological improvements in materials.

"We are presently looking for dielectrics of improved thermal stability, films with increased thermal conduction, and, in the area of printed circuits, rigid but machinable substrates.

"Many of the structural functions reserved formerly for metals are being replaced by high strength plastics. I believe our national economy will remain in a healthy competitive position because of this continuing effort to improve and apply."

R. C. Starkey

Senior Design Engineer, High Temperature Electrical R & D, North American Aviation Inc., Los Angeles.

"Temperatures of 800°F to 1200°F are becoming commonplace in aircraft, missiles, and space vehicles. These vehicles contain equipment that must be interconnected by electrical wire. The needed wire must withstand the high ambient temperatures plus the heat generated by the power loss in the conductor.

"Present insulations, including the exotic materials developed in the past

Natvar

TERAGLAS®

A NEW CLASS B INSULATION HAS RESILIENT WEAVE AND HIGH DIELECTRIC STRENGTH UNDER STRETCH

Natvar Teraglas is a new flexible insulating material comprising a base fabric, woven from polyester (polyethylene terephthalate, or "Dacron") warp yarns and continuous filament glass filler yarns, coated with an improved varnish, possessing exceptional dielectric strength under elongation. It will withstand Class B (130°C) operating temperatures.

In view of the higher dielectric strength of Natvar Teraglas compared to bias varnished cambric, thinner sections or fewer layers may be used to provide the voltage breakdown protection desired. Consequently, at comparable tape prices, a significant saving may be realized in production costs, while permitting up-grading to Class B (130°C) temperatures.

Natvar Teraglas is available in .008", .010", .012" and .015" thicknesses—in tapes, in full width rolls (36"), or in sheets. Ask for Data Sheet and Samples.

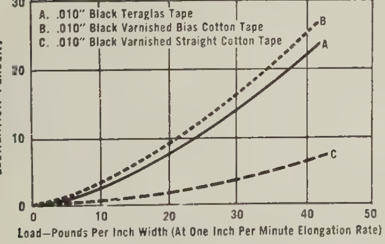
Natvar Teraglas will prove advantageous in many applications — for insulating motors, generators, transformers, cables, switchgear, busbars, and other apparatus and equipment where resiliency and high dielectric strength are desirable.

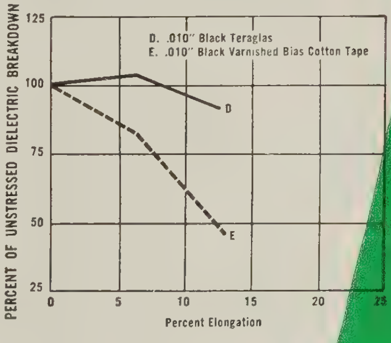
TYPICAL DATA

Physical Properties:		.008"	.010"	.012"	.015"
Approx. weight lbs./sq. yd.		0.43	0.54	0.62	0.77
Breaking Strength lbs./in. width	Warp	45	45	45	45
	Filler	100	100	100	100
Tear Strength, grams	Warp	1000+	1000+	1000+	1000+
	Filler	1000+	1000+	1000+	1000+
Elongation, % (Under 25 lbs./in. width —3 minutes)		9.5	7.5	7.5	7.0

Electrical Properties:	.008"	.010"	.012"	.015"
Elec. Breakdown Strength (C48-23-50 V/M)	1600	1600	1600	1600
Elec. Breakdown Strength (Under 6% stretch)	1600	1600	1600	1500
Elec. Breakdown Strength (Under 12% stretch)	1500	1450	1450	1300
Power Factor, %, at 80° C-50 V/M-60 c.p.s.	2.2	2.5	2.5	3.0

LOAD-ELONGATION CHARACTERISTICS FOR NATVAR BLACK TERAGLAS





Natvar

Natvar Products

- Varnished cambric—sheet and tape
- Varnished canvas and duck—sheet and tape
- Varnished silk and special rayon—sheet and tape
- Varnished papers—rope and kraft—sheet and tape
- Varnished, silicone varnished and silicone rubber coated Fiberglas*—sheet and tape
- Slot cell combinations, Aboglas®
- Teraglas®
- Isoglas® sheet and tape
- Isolastane® sheet, tape, tubing and sleeving
- Vinyl coated and silicone rubber coated Fiberglas tubing and sleeving
- Extruded vinyl tubing and tape
- Styroflex® flexible polystyrene tape
- Extruded identification markers

*TM (Reg. U.S. Pat. Off.) OCF Corp.

We will be very happy to supply information on any of our products on request.

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several years, have one or more vital weaknesses. The most promising insulations are either porous or inflexible. Either moisture reduces the insulating properties or the insulation cracks and spalls off when the wire is bent.

"Only one insulation system is available today that can be used. This is known as "MgO wire." However, in addition to being stiff and difficult to install, it is very hygroscopic and must be hermetically sealed to the equipment.

"All known, flexible inorganic insulations have virtually no dielectric strength when wetted with salt-laden moisture. Glaze-type coatings or impregnants that resist moisture are so inflexible they cannot be bent sharper than 200 times the wire diameter.

"In short, an insulation is needed like PVC, nylon, "Teflon," etc., that will last for long periods (500 hours) at temperatures over 750°F. In addition to temperature stability, flexibility, and moisture resistance, it should have the following characteristics:

1) Dielectric strength of 200 volts/mil, minimum at high temperature.
2) Capable of 20 O.D. bends, maximum.
3) Insulation resistance of 1.5 megohms per 50 ft. of wire.
4) Resistance to thermal shock of 150°F/minute.
5) Flexible at —65°F.
6) Resistance to new exotic fluids.
7) Abrasion resistance if possible.
8) Corona resistance at 150,000 ft.
9) Carbon-track resistance.
10) Fatigue resistance.
11) Ozone resistance.
12) Fungus resistance.

"Without such an insulation, the progress of electrical systems will be impeded and new flight vehicles will be penalized."

Loren B. Griffith

Chief Engineer, New York Coil Co. Inc., Phoenixville, Pa.

"The present demand for smaller and more compact units and components along with increasingly higher voltage requirements has occasionally created some problems for us in the manufacture of transformers and coil windings. While some of the newer types of films have good insulation characteristics, we would like to see available at a reasonable cost plastic film or other types of insulating sheets with a much higher dielectric per mil of insulation thickness, and which would also provide less corona leakage. In addition, we would also like to see higher dielectric characteristics in impregnating and encapsulating resins, particularly in epoxies, than those now commercially available."

J. M. Schiller

Component Development, Radio Corp. of America, Somerville, N.J.

"The material requirements of the electrical industry as compared to other industries, such as toy, maintenance, or novelties, that consume large quantities of coatings, resins, and plastics are far more stringent and exacting. As examples, military electronic applications require a product to possess stability over broad ranges of temperature and humidity, predictable dielectric constants and loss factors over broad frequency ranges, high insulation resistance at operating temperatures, tracking resistance, dimensional stability, mechanical strength, reliability, and many other rigid properties specified by the various military and other agencies.

"To satisfy these needs, and to compete for a share of this tremendous (if not exasperating) market, vendors have responded with an endless array of products, literally a flow of obsolescence. Each improved product, so the advertisements state, possesses superior properties. With the number of products currently being marketed, it would take sizeable laboratory facilities to properly evaluate those products considered to have

the specifications desired. Oftentimes we find, after shake-down or more lengthy testing, that these products do not live up to their stated claims. Other materials users, without adequate facilities for testing, select materials after considering the vendors data and claims, a most perilous path to follow these days, unfortunately.

"It appears that industry today feels impelled to improve existing materials by replacing them. In actuality, we have a good deal to learn about the materials currently being marketed. Vendors must learn to report reliable, meaningful test data; they must develop techniques to make their products uniform and dependable; they must seek to reduce or eliminate those impurities that hasten or cause deterioration; they must give greater consideration to fiber or filler materials and their treatment; they must insist on uniform raw materials and develop dependable processes of manufacture; and they must mature beyond being peddlers into sound, trustworthy suppliers who thoroughly understand and accept the realities of their products, be they good or undesirable.

"It is recognized that stability and degradation are at opposite sides of the scale and that the stability of polymers to environmental and electrical energies influences this balance. Chain scission, cross-linking, modification of side groups of the polymers, and cyclization—each of these degradation reactions affect the performance and life of a material. With this knowledge, improved test methods, and expanding technology, causes of failure can be more readily interpreted and more meaningful data accumulated. A more comprehensive knowledge of existing materials should be sought, and with this technical and performance data, selection of proven materials made.

"To bring about increased uniformity, controls, and standardization, test methods and standards are being steadily developed by such agencies as ASTM Committee D-20 on plastics and Committee D-9 on electrical insulating materials, NEMA, and others including the government agencies.

"It is essential that test methods become universally adopted so that a common denominator can be used to compare data obtained in conformance with specified conditions and procedures.

"Standardization, considered in all its ramifications, is unquestionably an essential tool toward improving existing materials. Usage analysis, in addition to test data, will provide the historical background essential to proper use of existing materials. All inroads toward understanding the limitations of materials, allowing for engineering safety factors, will enhance reliability and life expectancy.

"There is presently a need for dependable materials capable of continuous operation at 200° to 300°C and intermittent use to 500°C that can be readily processed and that provide the requisite physical, electrical, and environmental properties. Materials with improved resistance to radiation would enhance our efforts to engineer insulated products for our space programs. Aging characteristics of plastics need up-grading, and perhaps materials designed for specific conditions of exposure would extend the life expectancy of materials.

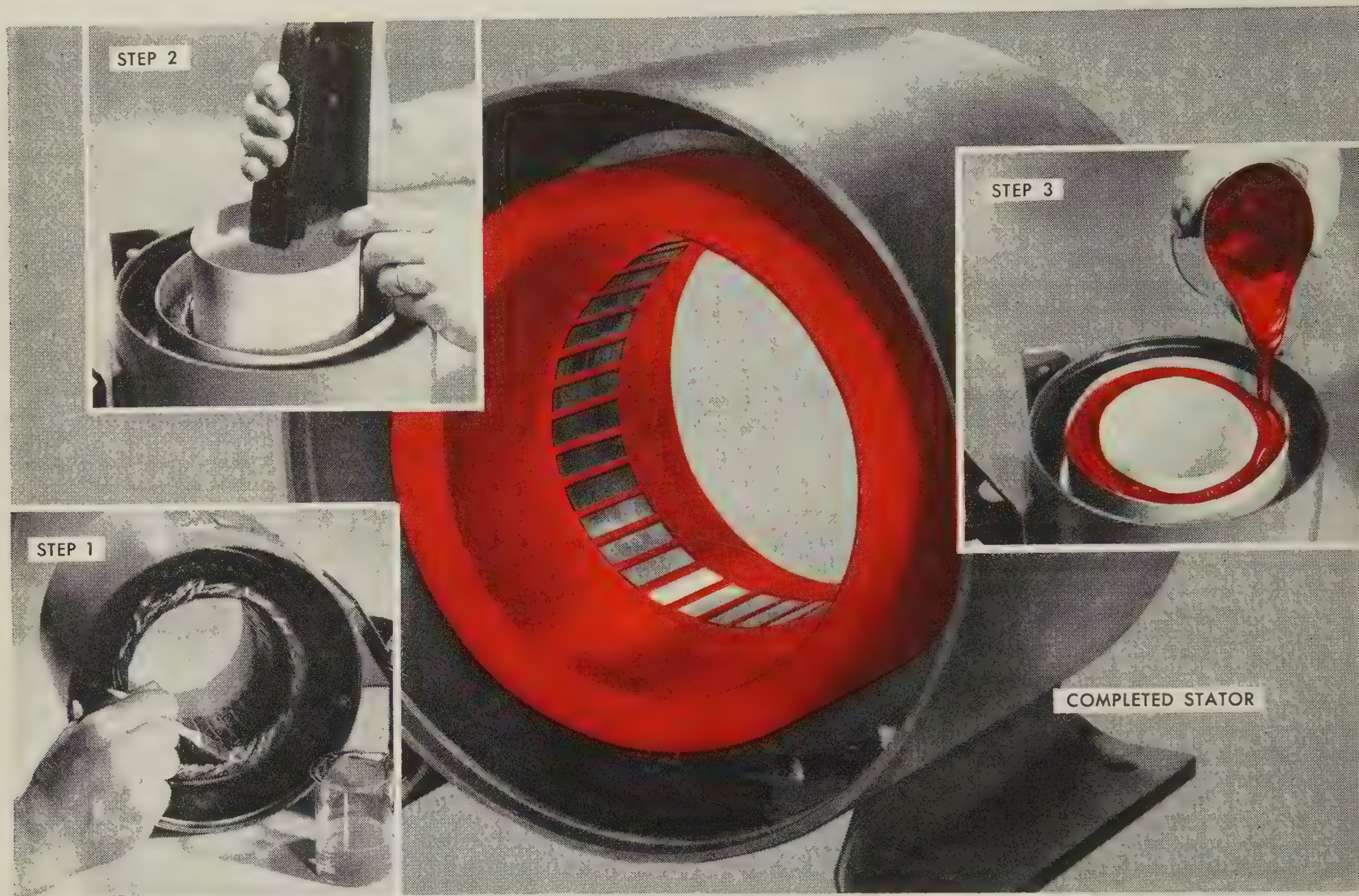
"I should like to see powdered plastics for the fluidized bed process that can be processed at 100°C, or pelletized for use in transfer molding. Silicone resins that cure at 100°C, have low vapor transmission rates, and possess thermal and electrical properties equivalent to those cured at 150-200°C would find a waiting market.

"The polyaluminoxane (aluminum-oxygen backbone with organics as the limb constituents), phosphinoborines (phosphorus-boron bred with organic linkages), and the semi-organic derivatives of siloxyanylferrocenes, and other hybrid polymers are of interest and should open new avenues toward obtaining new products for the foreseeable future.

"With a view to the future, it is essential that we do not obsolete materials of today before they are thoroughly evaluated and their use potential exhausted."

SILICONE NEWS from Dow Corning

Fulltime Protection...



New, Easy-to-Use Silicone Encapsulant Beats Heat, Cold, Moisture, Abrasives

Encapsulating motor end turns with Silastic® RTV, the Dow Corning liquid silicone rubber, produces a clean-cut protective jacket that inspires customer confidence. This confidence is not misplaced . . . the protection is just as effective as the encapsulation suggests.

Sure Protection New Silastic RTV especially developed for this purpose pours bubble-free . . . flows smoothly into all crevices . . . and leaves no weakening air holes or thin sections. Setting up, the rubber takes an iron grip on previously primed surfaces, and quickly vulcanizes into a void-free, homogeneous silicone rubber barrier to dust, dirt, moisture, abrasives, many chemicals, and corrosive atmospheres.

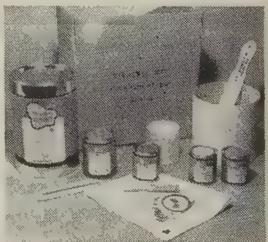
When cured, the silicone rubber jacket expands and contracts with windings and laminations . . . will not hairline crack.

For All Motors Equally suitable for Class A, B, F, or H insulation systems, Silastic RTV encapsulation protects against adverse environments and weathering . . . makes costly motor enclosures unnecessary.

Easy Processing Applying the protection is easy and time-saving. Here's all you do—1. paint end turns and lamination surfaces with primer; 2. put simple, easily constructed forms in place; 3. pour catalyzed Silastic RTV over coil end turns. That's all there is to it. The molded jacket cures at room temperature.

Available in Kits

Handy kits containing everything you need for encapsulating motor end turns are available from the Authorized Distributor of Dow Corning silicone materials in your area. Contact him today. He supplies quality silicone materials that offer economical solutions to your pressing insulating problems.



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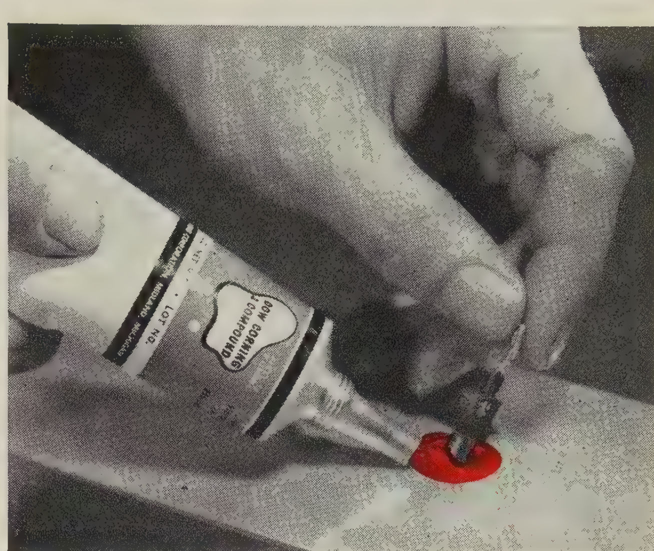
Full information and technical assistance is available by writing Dept. 4512.

first in silicones

Dow Corning

Plus Top Performance



Silicones Pack Power in Small Space

To assure reliability of transformers supplying standby power for submarine nuclear reactors, Milro Controls Company chose silicone insulating components and Dow Corning 997 Varnish.

Reasons for their choice: silicone resin insulation systems provide maximum output for minimum weight, superior resistance to moisture, and ample protection against high ambients and overloads. The impregnating varnish, Dow Corning 997, easily withstands operating temperatures up to 250 C. It provides superior protection against all the well-known enemies of electronic and electrical equipment. Each Milro power supply contains three compact, lightweight transformers.

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Compound Cushions, Conducts Heat

A dab of greaselike Dow Corning 3 Compound provides this diode with a ready-made heat transfer path from diode to washer, washer to chassis. As a heat-sink sealant, 3 Compound improves heat dissipation because of its good thermal conductivity, retains this ability . . . never dries out.

A similar product, Dow Corning 5 Compound, is widely used by semiconductor manufacturers for potting transistors. It retains initial consistency from −75 to 200 C . . . cushions vibration and shock. Completely inert and free of mineral salts, it protects against contaminants . . . blocks welding spatter . . . prevents damage to the wafer or junction . . . assures fewer rejects and helps provide superior performance of the semiconductor device.

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Contact the nearest Dow Corning Authorized Distributor. He's your best source for Silastic RTV and other quality-produced, performance-engineered silicone materials.

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National Electric Coil Company
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Prehler Electrical Insulation Co.
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Dates to Circle

Meeting and Convention Notices

Nov. 30-Dec. 2 . . . Ninth Annual Symposium on Technical Progress in Communication Wires and Cables, sponsored by The U. S. Army Signal Research and Development Laboratory, Berkeley-Carteret Hotel, Asbury Park, N.J.

Dec. 5-7 . . . EIA, Third Conference on Maintainability of Electronic Equipment, Hilton Hotel, San Antonio, Texas.

Dec. 5-8 . . . Third National Conference on the Application of Electrical Insulation, Conrad Hilton Hotel, Chicago.

Dec. 13-15 . . . Eastern Joint Computer Conference, sponsored by IRE, AIEE, and Assoc. for Computing Machinery, New Yorker Hotel and Manhattan Center, New York City.

Jan. 9-11 . . . AIEE-IRE-ASQC, 7th National Symposium on Reliability and Quality Control, Bellevue-Stratford Hotel, Philadelphia.

Jan. 16-18 . . . American Astronautical Society, 7th Annual Meeting, Sheraton-Dallas Hotel, Dallas, Texas.

Jan. 16-20 . . . Western Winter Radio-Television & Appliance Market (Division of Western Home Goods Market), Western Merchandise Mart, San Francisco, Cal.

Jan. 23-27 . . . Gaillard Seminar on Industrial Standardization, Engineering Societies Building, New York City.

Jan. 24-27 . . . SPE, 17th Annual Technical Conference, Shoreham and Park-Sheraton Hotels, Washington, D.C.

Jan. 29-Feb. 3 . . . AIEE, Winter General Meeting, Hotel Statler, New York City.

Jan. 30-Feb. 3 . . . ASTM, Committee Week, Netherland-Hilton Hotel, Cincinnati.

Feb. 1-3 . . . 2nd Winter Military Electronics Convention, sponsored by the National Professional Group on Military Electronics and the Los Angeles Section of IRE, Biltmore Hotel, Los Angeles.

Feb. 5-11 . . . National Electrical Week.

Feb. 7-9 . . . SPI, 16th Reinforced Plastics Division Conference, Edgewater Beach Hotel, Chicago.

Feb. 15-17 . . . AIEE, IRE, and the University of Pennsylvania, International Solid-State Circuits Conference, University of Pennsylvania and the Sheraton Hotel, Philadelphia, Pa.

Feb. 26-Mar. 1 . . . First Annual Pacific Electronic Trade Show, Great Western Exhibit Center, Los Angeles.

Mar. 15-17 . . . EIA, Spring Conference, Washington, D.C.

Mar. 20-23 . . . IRE, National Convention, Coliseum and Waldorf-Astoria Hotel, New York City.

Mar. 21-25 . . . Electrical Engineers Exhibition, Earls Court, London. For information, contact Electrical Engineers Exhibition Ltd., 6 Museum House, 25 Museum St., London, W.C.I.

Apr. 5-7 . . . AIEE, South East District Meeting, Jung Hotel, New Orleans, La.

Apr. 5-7 . . . ASTM, Symposium on Materials and Electron Device Processing, Benjamin Franklin Hotel, Philadelphia, Pa.

Apr. 17-21 . . . American Welding Society, Annual Convention and Welding Exposition, Commodore Hotel and New York Coliseum, New York City.

Apr. 19-21 . . . AIEE, Great Lakes District Meeting, Hotel Pick-Nicolett, Minneapolis, Minn.

Apr. 20-21 . . . SPI, 18th Annual Western Section Conference, Hotel del Coronado, Coronado, Cal.

Apr. 26-28 . . . IRE, 7th Region Technical Conference & Trade Show, Westward Ho Hotel, Phoenix, Ariz.

Apr. 30-May 4 . . . Electrochemical Society, Spring Meeting, Claypool Hotel, Indianapolis, Ind.

May 1-2 . . . AIEE, Rural Electrification Conference, Kentucky Hotel, Louisville, Ky.

May 7-8 . . . IRE, 5th Midwest Symposium on Circuit Theory, University of Illinois, Urbana, Ill.

May 8-10 . . . IRE, NAECON, Miami and Biltmore Hotels, Dayton, Ohio.

May 9-11 . . . Western Joint Computer Conference, sponsored by AIEE, IRE, and Assoc. of Computer Manufacturers, Ambassador Hotel, Los Angeles.

May 17-19 . . . AIEE, North Eastern District Meeting, Statler Hotel, Hartford, Conn.

May 23 . . . AIEE, Fractional Horsepower Motors Conference, Biltmore Hotel, Dayton, Ohio.

May 24-26 . . . EIA, 37th Annual Convention, Chicago.

Abbreviations Used in Notices

AIEE —American Institute of Electrical Engineers
ASTM —American Society for Testing Materials
ASME —American Society of Mechanical Engineers
ASA —American Standards Assn.
IRE —Institute of Radio Engineers
EIA —Electronic Industries Assn.
NEMA —National Electrical Manufacturers Assn.
NISA —National Industrial Service Assn.
SPE —Society of Plastics Engineers
SPI —Society of the Plastics Industry
WEMA —Western Electronic Manufacturers Assn.

How to Use Vulcanized Fibre for Electrical Insulation

by Earl A. Russell, Chief Engineer, Spaulding Fibre Company, Inc.

While all standard grades of Vulcanized Fibre can be used for many electrical insulating applications, the more exacting uses call for Spaulding's Electrical Insulation Grade — Armite.

Spaulding Armite is produced in thicknesses of 1/32 inch and under with a consistently higher dielectric strength than is available in other grades of fibre.

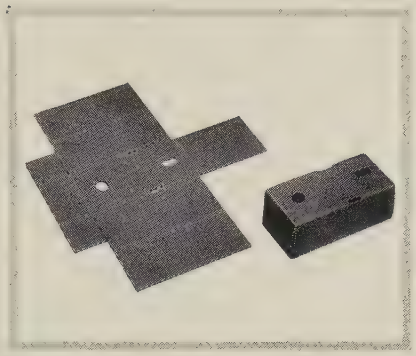
Special technical control of the manufacture of Armite makes it possible to combine this higher electrical quality with exceptional durability and forming qualities. Thus, Armite is particularly well suited for a wide range of both electrical and mechanical applications.

These uses include formed armature bonnets to insulate the windings from lead wires to the commutator, as well as for slot cell insulation in small armatures. Industry has also found extensive use for Armite in small, fractional horsepower motors. Here it is used in formed top sticks or wedges to insulate and anchor wires securely in the slots.

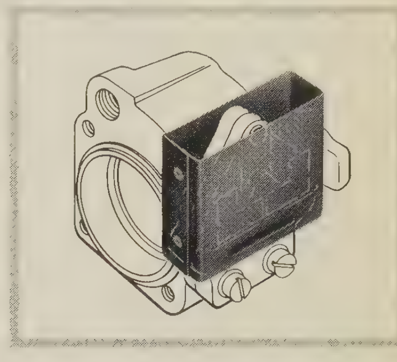
In "Barrier Insulation," the term used by Underwriters Laboratories for electrical insulation between live metal parts and adjacent live or ground metal parts, Armite finds one of its broadest applications. In this use, Armite insulators line the metal housing of electrical devices where space by itself is insufficient to provide gap insulation.

These Armite liners or "barriers" can be designed to accommodate almost any straight line contour. In .015″ or .020″ gauge Armite, fold lines are established economically by creasing in a punch press operation.

In thicker Armite, such as the more commonly used 1/32″, score lines are punched in a fast punch press operation. This permits folding to fit neatly inside the housing box. Whether creased or scored, Spaulding ships these parts flat and ready to be formed easily by hand for insertion.



For barrier insulation as switch box liner, Armite is creased in punching operation for rapid hand forming.



For barrier insulation as removable terminal cover scored and formed, Armite is held in shape with eyelets and in place with indent at base.

In these, as in a vast range of other applications, Spaulding Armite makes it possible to design and execute finished assemblies of assured electrical qualities without sacrificing economy.

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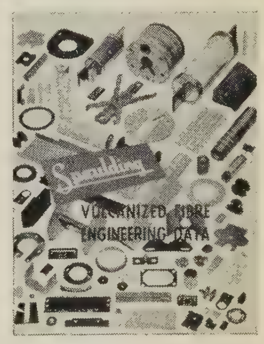

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Ionization Problems in Large Rotating Machines

By G. F. Lang, Manager, Insulation Development Section, Le Matériel Électrique, Schneider-Westinghouse, Champagne-Sur-Seine, France.

Abstract

This article discusses the laboratory work being done in France to define the *injurious* ionization inception concept as applied to large rotating machines. Various tests are run to determine the voltages at which discharges cause destruction of a given amount of insulation within a given amount of time. Descriptions of the test procedures, the equipment used, and the findings are presented. The problems involved in relating this work with test cells to measurements on coils and complete machines are discussed.

Introduction

The discharges which occur in occluded gases are among the phenomena affecting the aging of the insulation of stator coils in rotating machines. These discharges—due to a high voltage across the air gap—cause insulation wear by ionic bombardment and chemical action.

The first reaction of users of large rotating machines was to demand elimination of the ionization. This demand was based on the measurement of the ionization inception voltage.

We shall see hereafter that if the ionization inception voltage is an important factor in the determination of the damage caused by the discharges in a given void, it is not very significant in the case of a group of voids such as those which are found in practice in an insulation.

It seems to us useful at the present stage of our experience to try to define the concept of the injurious ionization inception; that is, the voltage at which the discharges attain a severity which is liable to cause the destruction of a given amount of insulation within a given time.

This study is faced, however, with an important problem; that is, the relation between the laboratory tests on cells and the measurements made on coils and even on complete machines.

Basic Concepts

1) *Distribution of the voltage in an insulation.* In order to avoid any misunderstanding we shall discuss the ideal cell shown in figure 1. This cell

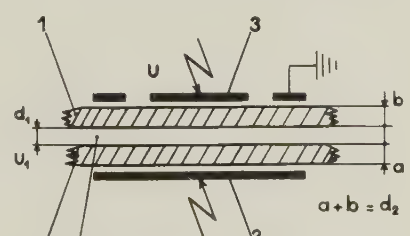

Figure 1, experimental cell consisting of (1) solid insulation, (2) air space, and (3) electrodes.

consists of a gas-filled gap with parallel faces, located between two plates of solid insulation, the faces of which are also parallel. The electrodes which are placed on either side of this cell are designed to produce a homogeneous electric field.

When this system is subjected to an alternating field, the voltage is distributed over the various elements in accordance with the following equations (suffix 1 for the gas and suffix 2 for the solid insulation):

$$\frac{U_1}{U_2} = \frac{d_1}{\varepsilon_1} \times \frac{\varepsilon_2}{d_2}$$

where d is the thickness and ε the dielectric constant.

Assuming that U_1 and U_2 are in phase and that the total voltage U applied to the cell is equal to:

$$U = U_1 + U_2$$

the voltage distribution equation becomes:

$$U_1 = U \frac{\frac{d_1}{\varepsilon_1}}{\frac{d_1}{\varepsilon_1} + \frac{d_2}{\varepsilon_2}}$$

For n insulating gaps in series we have:

$$U_n = U \frac{\frac{d_n}{\varepsilon_n}}{\Sigma \frac{d}{\varepsilon}}$$

These formulas may be used for a direct voltage provided the dielectric constants ε are replaced by conductivities Λ.

The equation can be used as long as gradient $G_1 = U_1/d_1$ in the gas-filled gap is less than disruptive gradient $G_d = U_d/d_1$. It may no longer be used when $G_1 \geq G_d$.

2) *Disruptive voltage in a gas-filled gap.* In the case of an air-filled gap, the disruptive voltage is given by the curve in figure 2 which has been

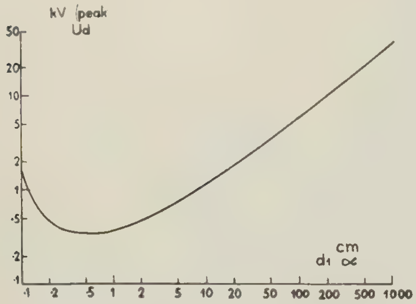

Figure 2, breakdown voltage of an air gap, expressed as a function of the product of the thickness of the air gap and the ratio of density of air under test conditions to density of air at 20°C and 1 mm of mercury.

studied more particularly by Paschen. It is expressed as a function of the product $d_1\alpha$, where d_1 = thickness of the air gap in cm and α = ratio of the density of air under test conditions to the density of air measured at 20°C under a pressure of 1 mm of mercury.

For gases that obey Mariotte's law or are very near to it, it is possible to replace the relative density by the pressure expressed in millimeters of mercury providing that one takes into account the temperature.

The curve in figure 2 shows a minimum value of 350 v (crest) for $d_1\alpha = 0.5$.

When all the calculations have been made we note that at 20°C and at atmospheric pressure, disruptive voltage U_d (expressed as a rms value) will be 250 v for an air gap of the order of 6.6×10^{-3} millimeters or 0.26×10^{-3} inches.

For higher temperatures, say from 100 to 200°C, U_d is lower than the value given at 20°C by 20 to 30%.

Very sensitive and specially designed equipment is, of course, required to detect these discharges at such low voltages.

Ionization Inception Voltage

Ionization inception voltage was often (and is still sometimes) used as a criterion of the ionization in the insulating barrier of machines. We shall examine the significance of the ionization inception voltage with respect to what has already been discussed. For this purpose we shall consider an insulation containing various voids of different dimensions.

Let us first consider again the cell shown in figure 1, the gap being filled with air at 20°C under normal atmospheric pressure.

The equation may be written:

$$U_1 = KU \quad \text{where} \quad K = \frac{\dfrac{d_1}{\varepsilon_1}}{\dfrac{d_1}{\varepsilon_1} + \dfrac{d_2}{\varepsilon_2}}$$

We shall assume that the dielectric constant ε_2 for solid insulation is equal to 5 (which is in practice the value for the mica insulation used on stator windings).

Under these conditions, the variation of K as a function of d_1 is given by the curves shown in figure 3 for

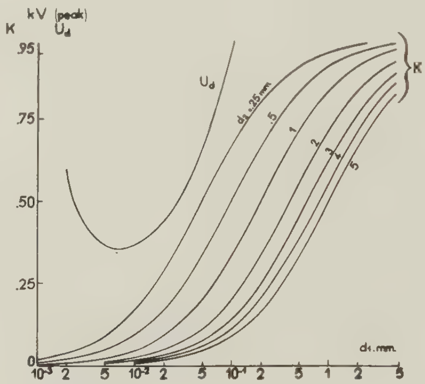

Figure 3, variation of K for different insulation thicknesses plotted as a function of air gap thickness. K is based on dielectric constants of 5 for the insulation and 1 for the gas-filled gap.

various values of d_2 (thickness of the solid insulation).

In this same figure we have plotted a part of the curve shown in figure 2, replacing the logarithmic ordinates by linear ordinates. The abscissae used are those from figure 2 ($d_1\alpha$). In this expression we assume that α is equal to 760 mm (normal atmospheric pressure) for the sake of simplicity and that the temperature is 20°C. α being constant, U_d can be expressed directly as a function of d_1.

Therefore, we have on the same graph:

$U_d = f(d_1)$ and $K = \vartheta(d_1)$

We know that $U_1 = KU$

By multiplying the ordinates of each of the curves $K = \vartheta(d_1)$ by a value of U, we obtain several sets of curves:

$U_1 = U\vartheta(d_1)$

each curve being applicable for a well defined value of U and d_2.

For a value of d_2 [therefore for one of the curves of the set $K = \vartheta(d_1)$] there is a particular value of U (that we shall call U_i) where curve $U\vartheta(d_1)$ is tangential to curve $U_d = f(d_1)$ at a point whose coordinates are $U'_1 d'_1$. This particular value (U_i) of U is no other than the ionization inception voltage of the system, the thickness of which is d_2, under accepted test conditions (cell of figure 1, pressure: 760 mm of Hg, 20°C, air).

Figure 4 shows the respective varia-

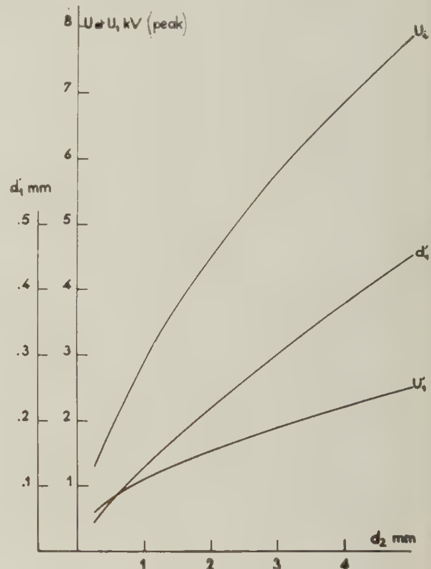

Figure 4, minimum inception voltage of the cell (figure 1) versus the thickness of the solid insulation.

tions of U_i, U'_1, and d'_1 as a function of d_2.

d'_1 = "optimum" thickness of the air gap in order that ionization inception will occur when voltage U applied to the system is as low as possible.

U'_1 = value of voltage U_1 across the air gap having a thickness d'_1, at the precise instant when the first discharge occurs.

U_i = minimum value of voltage U to be applied to the system so that discharges will occur in the air gap. *U_i is the ionization inception voltage of the system being investigated.*

On these curves, a 3-mm (0.118-in)

mica insulation placed in a cell of the type shown in figure 1 has a minimum inception voltage of 4 kv (rms value) when the thickness of the insulation is 0.3 mm (0.012 in).

The voltage applied to this air gap is then of the order of 1.9 kv.

We have chosen this example because it corresponds to the thicknesses of insulation used in normal practice for stator coils with a rated phase-to-phase voltage of 10 kv rms, or a rated phase-to-ground voltage of 5.8 kv rms.

Therefore, theoretically, after taking into consideration the hypotheses stated, 30% of the coils located on the phase end of the machine would reach the ionization inception voltage in service under normal operating conditions if they contained voids of 0.3 mm.

It is important to note that if the thickness of the voids was greater or smaller than 0.3 mm, ionization inception would only be reached for higher values of voltage.

The theory which we have just examined is also applicable in practice to the insulation of coils but the values are very different for the following reasons:

1) The insulation of stator coils does not contain any gaps with parallel faces as in the ideal case of the experimental cell shown in figure 1. The surfaces of the voids in stator coil insulation are very irregular. Therefore, the electric field does not have the homogeneity specified for the study of the cell shown in figure 1.

2) The convergence of the lines of force of the field produces local voltage gradients which are higher than those foreseen by the cell under study. It would therefore be necessary to consider the curve shown in figure 2 in which the ordinates would be expressed in terms of the voltage gradient

$$\frac{U_{d_1}}{d_1}.$$

The curves shown in figures 3 and 4 should be utilized in the same way.

It is easy to understand that under these conditions of concentration of lines of force, the ionization inception voltage is lower for the same values of d_2 and d_1. It can also be assumed that one reaches the ionization inception voltage for the same value of d_2 but for a much lower value of d_1.

There are still other factors which affect the foregoing theoretical results. For instance, we do not know the pressure of the air occluded in the voids, but we assumed it to be 760 mm for our calculations. An increase in pressure displaces curve $U_d = f\ (d_1)$ towards the left (see figure 3) which amounts to increasing the ionization inception voltage, and this process is reversed when the pressure is reduced. If the ionization inception voltage is the same but the pressure is higher, the thickness of the air gap will be smaller.

Now we know that the pressure in a void may vary within a wide range depending on the materials used and the method of manufacture.

Temperature also has a certain influence on the levels of these parameters—especially if the void is completely closed, as this causes an increment in pressure when the temperature increases.

We assumed that the gas was air. Actually, in an insulating barrier the voids contain mostly gases from the organic components of the insulation, and this slightly displaces the curve discussed in figure 2.

Inasmuch as each of these parameters has an important effect on the ionization inception level, one conceives that the curves shown in figure 4 are more suitable for getting an idea of the phenomenon than for being applied directly to a practical case. Taking these facts into consideration, we note that the ionization inception voltage measured on the insulation of a winding is the ionization inception voltage for one or several voids meeting optimum conditions (geometry of the void pressure, nature of the gas, etc.).

However this does not give any information on the other voids which are generally more harmful than those detected. Therefore, while the ionization inception voltage seems to be of little interest when measured on a machine or a winding, it is valuable for the theoretical study of the elementary discharges in a given air gap. This determines the conditions of the discharges in this void by changing their number per unit of time.

Parameters Affecting the Harmfulness of Ionization

It is beyond argument that ionization is one of the causes of the aging of insulation in commercial service. The rate of aging is dependent on the various parameters which affect the severity of the ionization.

1) *Mechanism of the discharges.* The voltage required to break down the air gap of the experimental cell shown in figure 1 is a function of the number of molecules comprised between the two electrodes for a given surface of these electrodes. This is shown by the curve of figure 2 where the abscissae are a product of the thickness of the gas-filled gap and the relative density of the gas.

In actual fact, a number of discharges will be produced at various points by increasing the voltage at the terminals of the cell in order to reach the ionization inception voltage.

Let us isolate one of these points and let us study the mechanism of the corresponding discharge (see figure 5a).

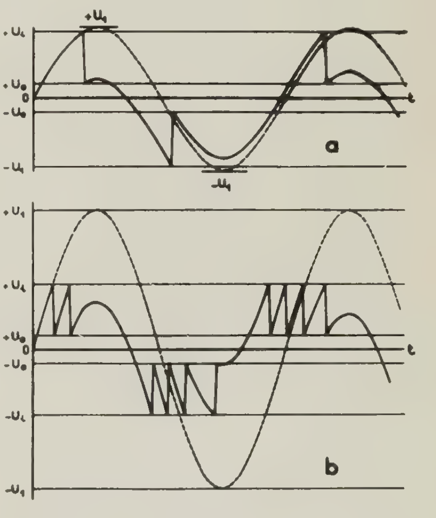

Figure 5, mechanism of the discharges: (a) one discharge per half-cycle, and (b) several discharges per half-cycle.

The voltage at the terminals of the electrodes is sinusoidal and of the form:

$$U = U_o \sin (\omega t + \rho)$$

The voltage across the air gap in the absence of any discharges will assume the form which we have already

seen:

$$U_1 = KU \text{ or } u_1 = Ku$$

substituting for u:

$$u_1 = K\,U_o \sin\omega t$$

Angle ρ is the phase displacement of voltages u and u_1. It is the angle we have considered as negligible before.

A discharge will occur when $U_{1\,max} = K\,U_o$ is slightly higher than ionization inception voltage U_i given in figure 2. ωt is then slightly lower than $\pi/2$.

The discharge at that moment disturbs the distribution of the voltage in the cell, and our original equation is no longer applicable (concave portion of the curve shown in figure 2). The air gap is short-circuited during the very short time (of the order of 10^{-8} seconds) the discharge lasts by the conducting path it produces. The voltage across the air gap decreases until it is equal to a value U_e when the discharge dies out through lack of sufficient supply.

Voltage u_1 at the terminals of the elementary cell is again subjected to the sinusoidal variations which are imposed by voltage u applied at the terminals of the system, but the axes of coordinates are displaced.

In figure 5a we see that the effective voltage across the elementary air gap when the discharge has died out is equal at the instant being considered to:

$$u'_1 = u_1 - (U_i - U_e)$$

or

$$u'_1 = K\,U_o \sin\omega t - (U_i - U_e)$$

This voltage reaches a maximum value for $\omega t = \pi/2$, then decreases, passes through zero for $\omega t = \pi$, and then reverses. Voltage u'_1 reaches once more an absolute value which is close to U_i.

When voltage $u_1 \geq 2\,U_i - U_e$, a second discharge will occur during the same half cycle of the input voltage.

There will be n discharges during each half cycle (b in figure 5) according to the maximum value reached by u'_1. "n" is a whole number given by equation:

$$n = \frac{K\,U_o - U_e}{U_i - U_e}$$

There will be N discharges per second where $N = 2\,nf$, "f" being the frequency of the input voltage.

Therefore, all other conditions being the same, there will be 20% more discharges for a system supplied on 60 cycles than for a system supplied on 50 cycles.

Voltages of 25 or 16⅔ cps are in this respect very favorable. One will also understand that by increasing the thickness, when considering the portion of the curve of figure 2 on the right of the minimum value, voltage U_i increases. This is equally applicable to the amplitude of the discharges. For this reason the ionization inception voltage is a very useful parameter in the study of the elementary discharge.

2) *Ionization level.* We can consider that aging due to ionization is linked not only to the frequency of the input voltage but also to the ionization level determined by a) the number of discharges per input voltage alternation, and b) the amplitude of each discharge.

To study this basic problem we used a cell of the type shown in figures 6 and 7. In designing this cell,

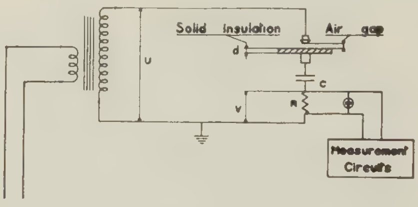

Figure 6, schematic diagram of the experimental cell circuit used to study ionization.

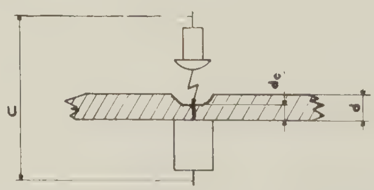

Figure 7, schematic diagram showing erosion of an insulation sample in the experimental cell.

we wanted to isolate the elementary discharge phenomenon in order to have only one point of discharge for better study.

A cylindrical electrode is placed opposite a hemispherical electrode. They both have a diameter of 3 mm (.118 inches), and the gap between them can be adjusted at will — the upper electrode being mounted on a supporting screw. The thin piece of insulation, the thickness of which is of the order of 0.1 mm (0.004″), is placed between the electrodes and stuck to the lower cylindrical electrode with insulating varnish. This should be done very carefully in order to avoid occluded air bubbles between the insulation and the electrode which would introduce errors into the readings because of their ionization.

The electrode system is connected to a variable voltage and frequency supply circuit—a transformer which supplies up to 10 kv and withstands 1500 cps.

In this case, the transformer is fed by a variable frequency electronic generator through a standard 60-watt amplifier.

The following elements are connected in series in the electrode circuit: a) A 1000-pf capacitor representing the solid insulation in series with the void. b) A 10^4-ohms resistor serving as a base for the measurement circuit.

This circuit may include several instruments such as an impulse counter and an oscilloscope (figure 8). A neon tube connected directly across the ends of the resistor lights up when the sample breaks down.

To study the ionization we used "Mylar" films. The cell was mounted in an air-conditioning oven in order to prevent uncontrolled variations of the surface resistivity due to ambient temperature and humidity.

The following results have been obtained: a) The number of discharges per half-cycle is a function of the applied voltage. In order to have a better grasp of these phenomena, this number was limited to a maximum of 5 discharges during each positive half-cycle. This result was obtained when the voltage applied to the system was of the order of 3 kv. b) The amplitude of the discharges increases in proportion to the thickness of the air gap.

3) *Study of aging by ionization.* The quantity of electricity required to break down the insulation was used as a criterion. It was noted that, in the absence of any chemical action, the quantity of electricity expressed in coulombs required to break down the insulation was constant for a given material, providing however that the

following was taken into account:

When the insulation is subjected to the action of the electronic bombardment, the insulation within the bombarded area deteriorates and its thickness gradually decreases with time (figure 7).

A stage will be reached where this thickness will be equal to a critical value d_c for which there is an intrinsic breakdown at the voltage applied to the cell. Under these conditions, the thickness d_i of the insulation actually destroyed by the discharges is equal to:

$$d_i = d - d_c$$

where d is the initial thickness of the insulation being investigated.

We note that for a given material

$$\frac{Q}{d_i} = \text{constant,}$$

Q being the overall amount of electricity required to break down the insulation.

By varying the voltage and the frequency within a certain range only, the time required for breakdown to occur is changed.

It may be difficult to measure "d_c." A dial indicator with a small plunger is used to measure this residual thickness. However if the output of the generator is too high, the breakdown is too destructive, and it may not be possible to measure "d_c."

In the example concerning the aging tests on a Mylar film described previously, the thickness d_i eroded by the bombardment was 0.044 mm or 0.0017 in. This result was obtained with a quantity of electricity Q of 48.10^{-3} coulombs; that is, 11×10^{-3} coulombs for a thickness of 0.10 mm or 27×10^{3} coulombs for a thickness of 0.10 in.

The same result (within 10%) may be obtained by varying the parameters successively as follows:

a) Frequency increased from 250 to 500 cps.

b) Frequency increased from 250 to 500 cps and thickness d_1 of the air gap reduced from 0.3 to 0.2 mm.

c) Frequency increased from 250 to 500 cps and voltage increased from 2200 to 2500 v. All other parameters remain unchanged.

In the last test for instance, it is significant to note that due to the increase in voltage, thickness d_i has decreased from 0.044 to 0.029 mm (0.0017 to 0.0011 in). In this same test, a voltage increase of 13½% and a doubling of the frequency reduced the time required for the insulation to break down from 7 hr to 2½ hr without changing the selected criterion Q/d_i.

All these results are repetitive. Each one is the average of the values obtained (with little dispersion) on 10 cells connected in parallel (figure 9). A one-hundred-way switch enables the use of only one measurement system (figure 8). We must expect, however, that it will not be possible to increase the test frequency indefinitely without introducing errors due to an abnormal temperature rise at the points of impact of the discharges. This temperature rise is liable to cause the destruction of the insulation due to thermal instability.

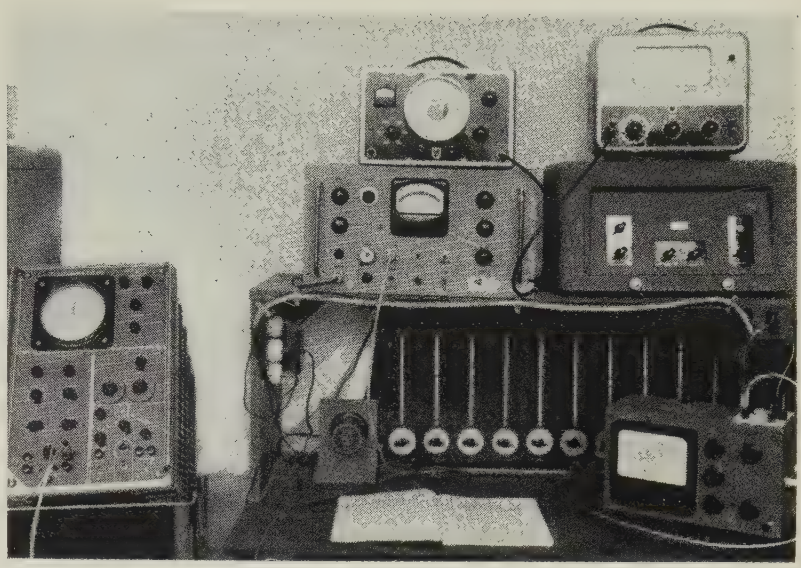

Figure 8, equipment used to feed and control the experimental cell.

Classification of the Materials

As we have already said, the experimental cell was designed originally with a view to studying the actual ionization. In view of the results obtained, it seemed to us that it could play a useful part in the classification of insulating materials, taking into account their resistance to electronic bombardment.

These are then characterized by Q/d_i = constant. It is important, however, to remember that ionization attacks the insulation in two ways—by electronic bombardment, and by chemical action.

The latter undoubtedly obeys slightly different laws and is linked with the nature of the occluded gas. It seems logical to investigate it separately in a different cell. It is quite possible that these laws are linked to the previously mentioned equations.

The proposed cell designed by the French Group of the IEC seems suitable for the study of the chemical action.

Ionization in Winding Insulation

The insulation engineer cannot be satisfied with laboratory studies, and he is obliged to consider the materials used — especially the insulation for the windings of large rotating machines operating at voltages above 5 kv up to 24 kv and occasionally at even higher voltages for ratings of a few to several hundred megawatts.

The quantity of electricity produced by the discharges in an insulation is measurable. Methods have been suggested in specialized magazines, but, when applying them, it is essential to note that ionization is a point phenomenon distributed erratically in the insulation.

It is therefore necessary to have methods for locating this distribution in order to detect the point or the points where the discharges reach a dangerous level for the life of the insulation.

Actually the overall ionization level

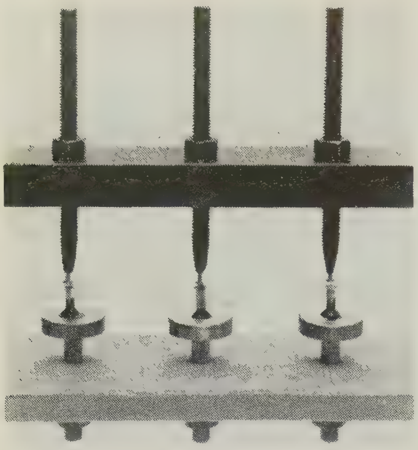

Figure 9, close-up of electrodes in the experimental cell.

for an insulation corresponds to the sum of the elementary levels of each discharge.

As far as we know there is not yet any direct method for evaluating the distribution and for locating the points of intensive discharges. The only way is to make several measurements with each one related to a limited surface of the insulation being investigated.

There are several methods—two of which we shall describe. The first one consists of measuring with a Schering bridge the value of the power factor at 0.4 and 0.8 U_n (U_n is the phase-to-phase voltage of the machine in which the coil being investigated will be mounted).

However, this method has disadvantages, and the results obtained on coils which are different in shape, size, and insulation cannot be compared.[1] Furthermore, it is based on the measurement of the power factor and is therefore affected by the chemical nature of the insulation.

The second method is based on the fact that the capacitor represented by a gas-filled void is practically short-circuited at the instant of the discharge (see figure 5).

By an increase in the number of discharges per alternation obtained by increasing the voltage, it is possible to short-circuit the void permanently. This is not entirely true, but in practice the error "E," if not small, is at least fairly constant and may be measured by means of preliminary tests.

The method then consists of measuring the capacitance C_L of the insulation at a sufficiently low voltage—0.2 U_n, for instance—in order that the ionization will not have any noticeable effect on the capacitance of the voids. We then measure capacitance C_H at a very high voltage—1.5 to 3 U_n for example—and calculate criterion:

$$M = \frac{C_H - C_L}{C_L} \times 1000$$

Criterion M enables us to appreciate the air occluded in the insulating barrier. It can be shown, in particular, that a theoretical air gap, uniformly distributed under the measuring electrode and having the same effect as the actual voids, would have a thickness

$$d_a = M \frac{d_s}{\varepsilon_s} (1 + E)$$

where d_s is the thickness of the insulation and ε_s its dielectric constant.

It can also be shown that criterion M measured on the whole insulation is the average (with capacitance weighting) of the elementary values m for all the partial elements of the insulation which are considered separately and which are as small as may be desired.

Therefore, it enables the comparison of elements of insulation of different dimensions. Finally, as it is entirely based on the geometrical capacitance, it is independent of the chemical composition and is, therefore, useful for comparing different kinds of insulation.

Trend of the Research

The study of ionization is far from being completed, since on the one hand we are only beginning to foresee the possibility of studying the resistance of materials to discharges and on the other hand we are only able to evaluate the voids trapped in the insulation.

At the present stage of our experience the obvious problem is still the connection between these two measurements. In other words, it will be necessary to determine for a given insulation the ionization inception voltage from which the ionization level must be considered as really injurious. This should be done by investigating the resistance of materials to discharges.

In parallel, it is necessary to improve the existing measurement methods for complete coils and to locate the discharges which are injurious to the insulation involved.

The trend of the investigations is by itself an important program in regard to its usefulness and extent.

It emphasizes the injurious ionization inception concept which should not be confused with the classical ionization inception concept shown by the curve of figure 2.

Conclusion

It would be wrong to draw a conclusion from an article on a problem which is still in the development stage. We may hope, however, that the research now in progress will proceed actively so that the laboratory results and the results obtained in practice may be correlated. A better knowledge of the basic phenomena affecting the discharges is also necessary to enable insulation specialists to make the necessary improvements.

At present with the new insulating materials, ionization does not appear to be the main agent of the aging of machines. This result was obtained by methods which were generally empirical, and we may expect that in the near future these will become more scientific, and hence more logical.

Bibliography

J. H. Mason, "Dielectric Breakdown in Solid Insulation," Progress in Dielectrics Vol. 1, Pg 1-59, Heywood and Cy Ltd., London (1959).

S. Whitehead, "Dielectric Breakdown of Solids," Clarendon, Oxford (1951).

J. Fabre, J. Laverlochere, G. Lang, G. Leroy, G. Narcy, G. Ruelle, Cigre Paper No. 137 (1956).

G. L. Moses, Trans. AIEE 70. Pt. 1 763 (1951).

S. I. Reynolds, "Voids in Insulation Under Internal Discharge," Power Apparatus and Systems (USA), Pg 1604-1608, Feb. 1959.

V. Adamec, Elektrotech, Obzor—Vol. 47—No. 8, Pg 417-423 (1958).

Clelland D. Nail, "Corona Discharge—The Failing of Dielectrics," Electronics Industries, USA Sept. 1958, Pg 74-77.

T. W. Dakin, N. M. Philowsky, W. C. Divens, "Effect of Electric Discharges on the Breakdown of Solid Insulation," Power Apparatus and Systems (USA), Pg 155-162, May 1954.

F. W. Peek, "Dielectric Phenomena in High Voltage Engineering," McGraw Hill, N.Y. (1929), Pg 245.

T. W. Liao, J. H. Hagenguth, "Impulse Corona—Detection, Measurement of Intensity and Damage Produced," Trans. AIEE Vol. 71, Technical paper 52-105, Pg 461-5, Dec. 1951.

J. G. Anderson, "Ultrasonic Detection and Location of Electrical Discharges in Insulating Structures," Trans. AIEE, Technical paper No. 56 744.

[1] See "Investigation of a Practical Criterion for Controlling High Voltage Insulation," G. F. Lang., Bulletin de la Ste Francaise des Electriciens, 7e serie,—Tome IX, No. 102, June 1959.

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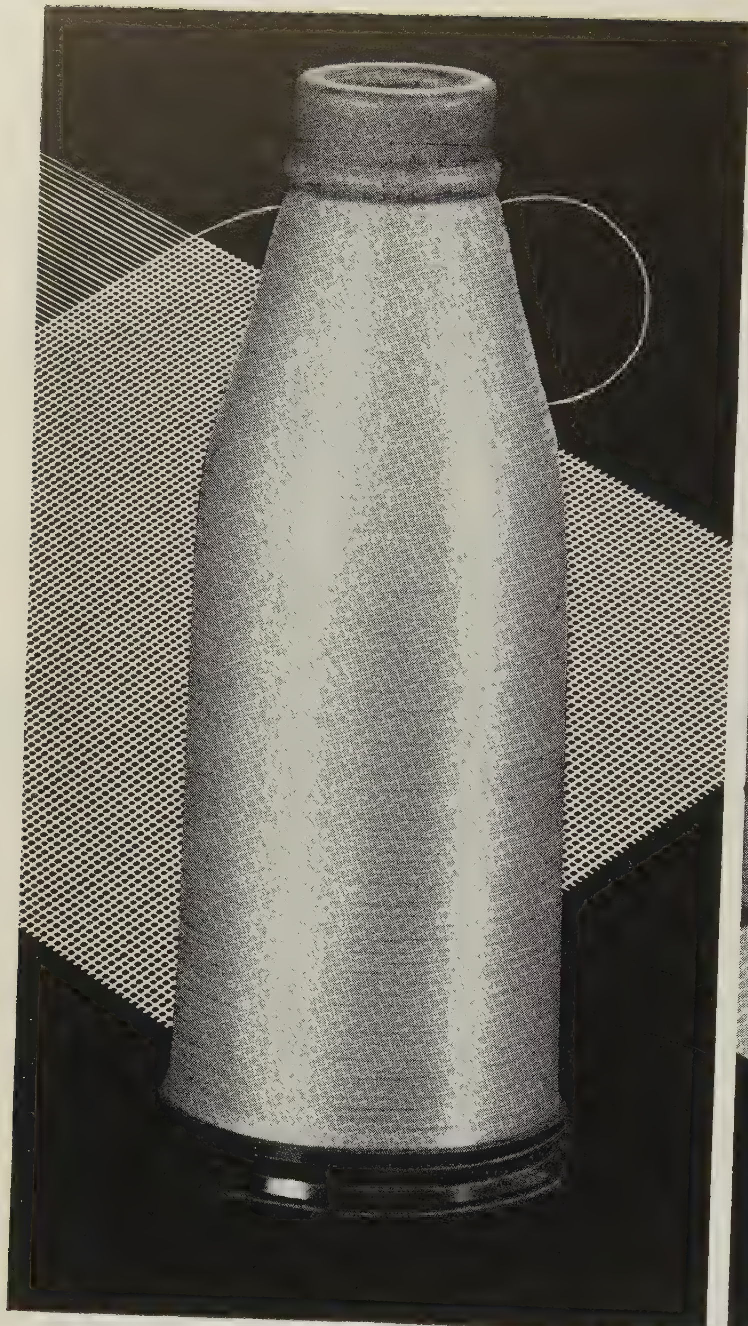

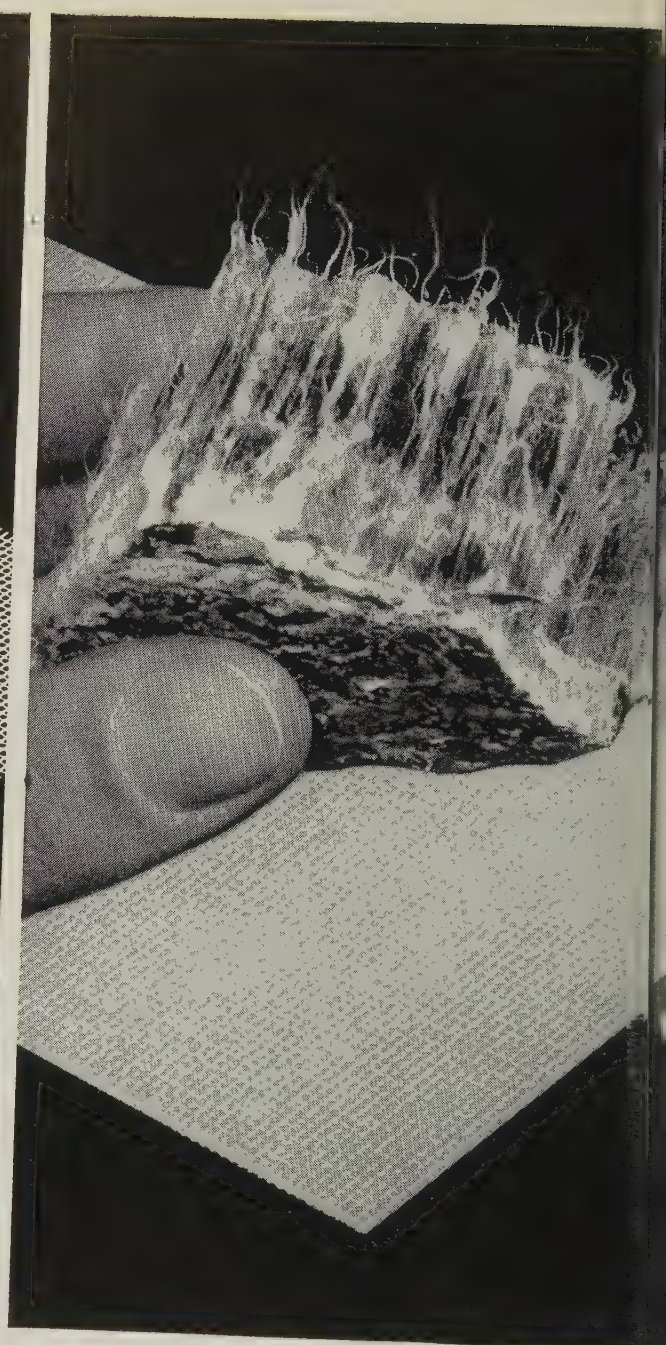

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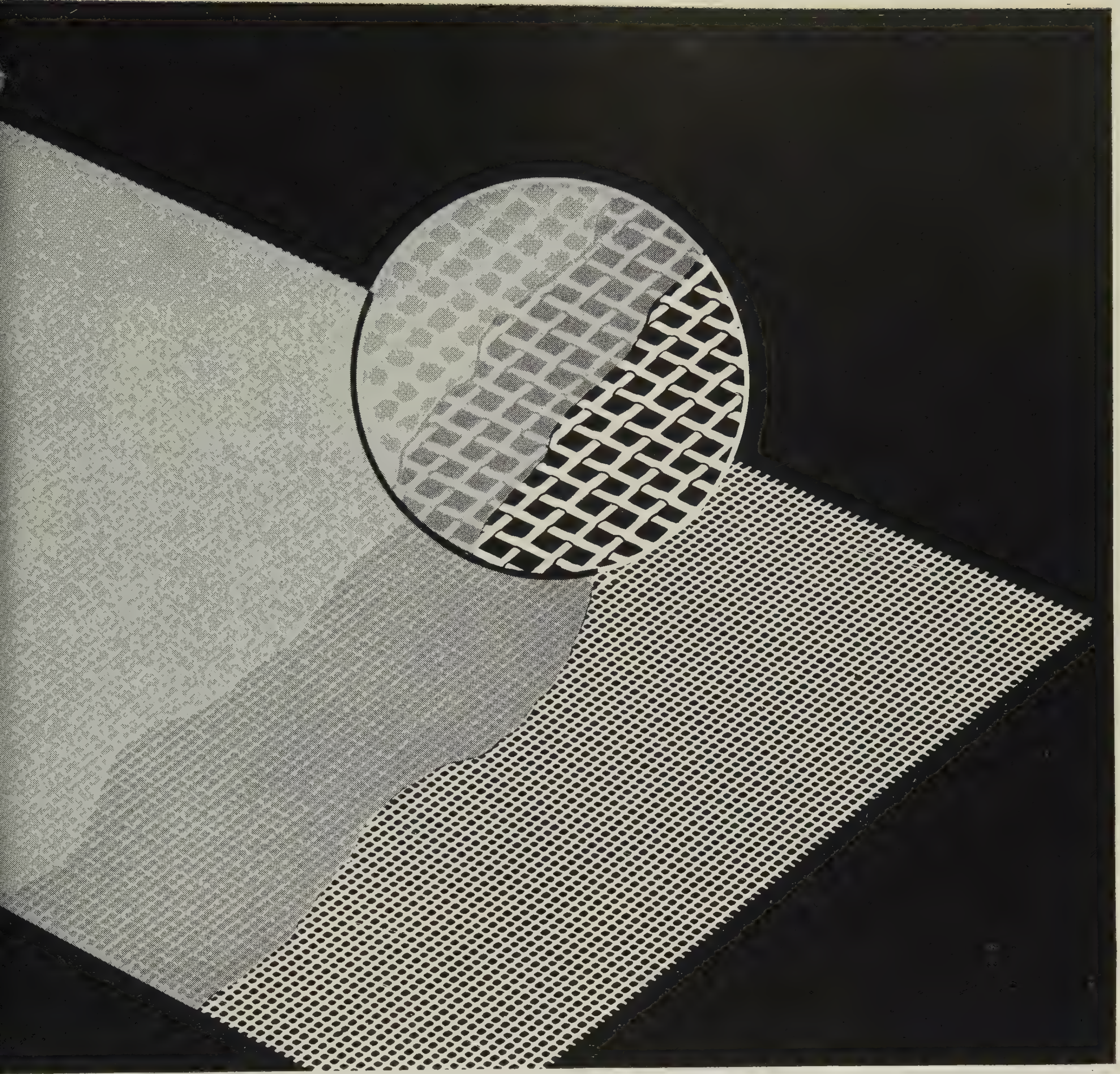

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Cavities and Corona in Insulations Impregnated with Liquid Dielectrics

By Dr. N. Klein, Electrical Engineering Dept., Technion-Israel Institute of Technology, Haifa, Israel.

Electrical breakdown of equipment often originates in cavities included in the insulation and much effort is being spent to determine the properties of cavities. These properties are especially involved in insulations impregnated with liquid dielectrics and the designer of power cables, capacitors, transformers, etc., is confronted with a number of complicated phenomena connected with the cavities.

To give examples: it is known that the mechanical pressure in power cables can, on no load, decrease to values close to vacuum, or that the pressure in sealed transformers is subject to large variations. The reason for these effects is found in the solution of gases in the impregnant. It is well known also that in equipment on load the number of cavities has considerably decreased. The opposite effect is found on cooling and the number of cavities and corona in the impregnant increase often to a great extent. The reason for these effects is again gas solution and cavitation in the liquid.

While the designer wants to know about expected mechanical pressure changes in planned equipment, his main interest in cavity behavior arises from its influence on the lifetime of the insulation. The cavities are subjected during operation to continuous variations in size, shape, gas pressure, and kind of gas. In addition, cavities vanish and new ones form. All this has a bearing on the expectation of corona in the insulation and hence on insulation life-time.

This article will show what influences the behavior of cavities, how their sizes and gas pressures can be foretold, how the likelihood of corona can be estimated, and how corona can be decreased by suitable design which changes cavity properties.

Corona Inception Voltage

Investigation of corona in the insulation is based upon data on voltages at which corona starts in a cavity.

The inception voltage V_i for corona in cavities is estimated with the help of Paschen curves. Figure 1 shows these curves for air, nitrogen, and hydrogen, when gas fills the space between plane, parallel surfaces. The inception voltage V_i appears as a function of the product of gas pressure p_c and distance d of the bounding surfaces. It is useful to derive a set of curves from the Paschen curves, giving the electric field E_d in the insulation, close to a cavity, at corona inception.

Figure 2 shows E_d as a function of d, with gas pressure p_c as the parameter. When the gas is nitrogen, the cavity is lens shaped* and the dielectric constant of the insulation is 4. Two well known facts emerge from this figure: the likelihood of corona in the insulation decreases when a) the pressure increases, and b) when

*More accurately, when the cavity dimension in field direction is very much smaller than perpendicularly to it.

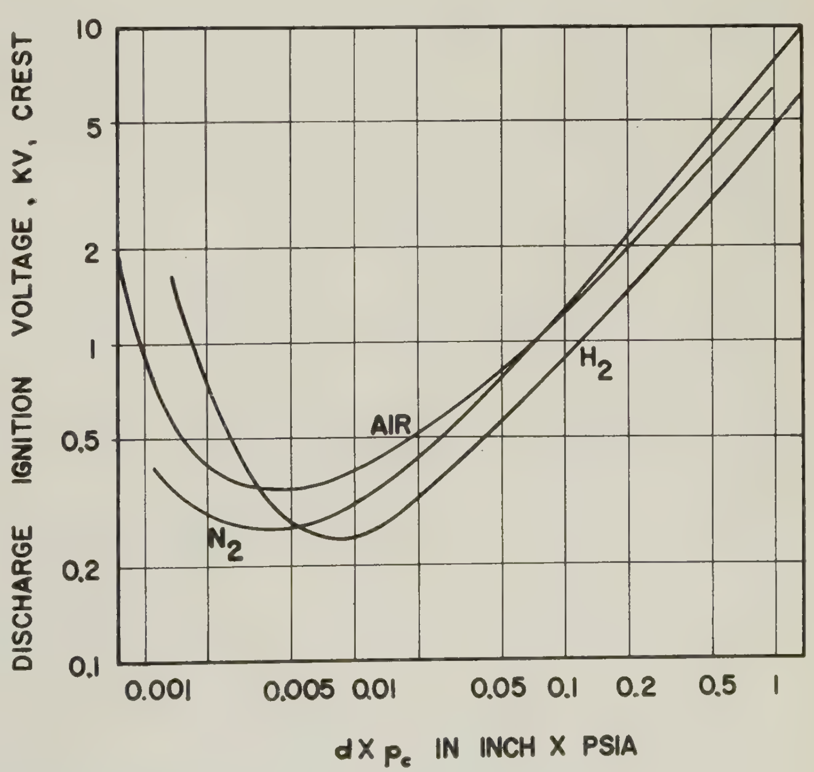

Figure 1, Paschen curves for air, nitrogen and hydrogen.

the cavity size decreases. Ample use is made of these properties of gases, e.g. by filling high voltage apparatus with high-pressure gases, by applying thin paper tapes around cable conductors to limit cavity sizes, and many others.

The essential variables determining corona are thus: size of cavity, gas pressure, and the kind of gas. The question is how to foretell these cavity properties in impregnated insulations.

Gas, Cavity Size, and Surface Tension

The gases occurring in the cavities are primarily those included in the insulation at manufacture. Changes can occur, however, during operation in the gas content of the insulation by gases entering the apparatus from outside and by gaseous decomposition products produced by corona, heat, or other reasons. It is often not certain what these changes in gas content will be, and estimates of corona inception voltage have to be on the conservative side.

The total cavity volume of an apparatus depends upon the quality of impregnation. It is usually possible to determine the cavity sizes which occur frequently and which are typical for an apparatus. Such cavities occur in the liquid at certain locations, and their size depends upon distances of solid bounding surfaces. Illustrating this in a power cable, cavities can occur among other places in the stranded conductor or between paper tapes of the insulation, and in these cases the magnitude of typical cavities is determined by the space between strand wires and by the thickness of paper tape gaps respectively.

While kind of gas and typical cavity sizes can be determined in a comparatively simple way, the estimation of the gas pressure is involved as it depends upon many factors such as surface tension, gas solution in the impregnant, temperature changes, processes of cavitation, corona, and others.

The surface tension tends to decrease the size of a cavity and the pressure in the cavity p_c is therefore always larger than the pressure p_e in the impregnant around it. For a spherical bubble in the steady state the relation connecting p_e and p_c is simply

$$p_c = p_e + \frac{4\sigma}{d}$$

where σ is the surface tension of the impregnant and d the cavity diameter. $\sigma = 2\times10^{-4}$ lb/inch for oil and the pressure difference $p_c - p_e$ is only 0.0128 psi for a 1/16″ diameter bubble.

On the other hand, $p_c - p_e = 1$ psi for a tiny 0.0008″ dia. bubble. The importance of the variations of these pressure difference values will be apparent when discussing the disappearance of small cavities.

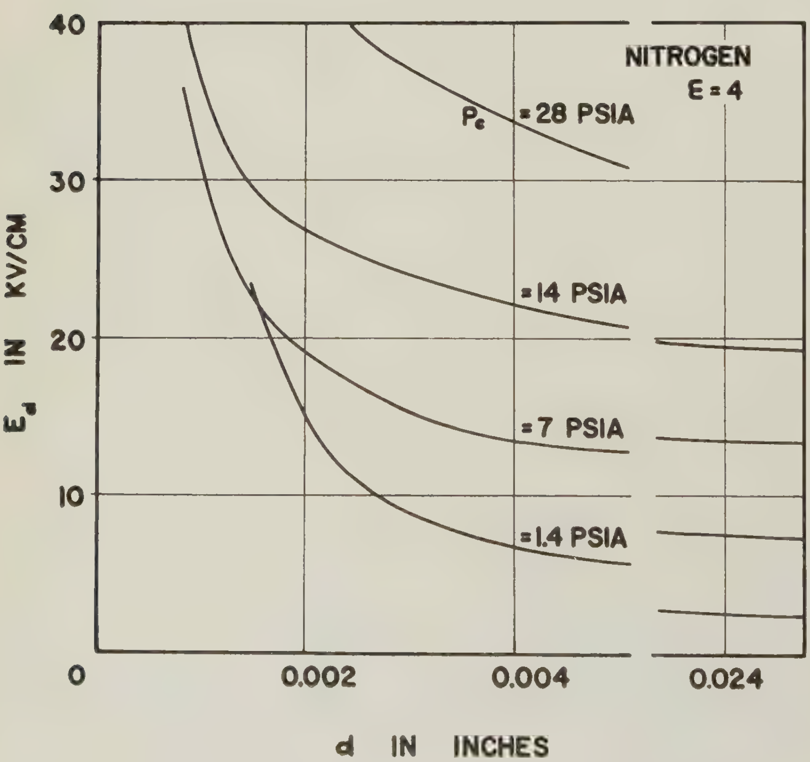

Figure 2, discharge inception stress E_d as function of cavity thickness d and pressure p_c when the dielectric constant is 4.

Solution of Gases Causes Changes in Cavities

The second and very important property influencing cavity pressure is the solution of the gas in the surrounding liquid. The solution leads to a state of equilibrium of the gas in the cavity with the dissolved gas, and this is defined by Henry's law:

$$\gamma = \frac{c_{es}}{c_{cs}}$$

Here γ is the solubility coefficient, and c_{es} and c_{cs} are steady state gas concentrations in the impregnant and cavity, respectively. The magnitude of γ varies considerably and is 0.075 for nitrogen in oil and 1.0 for CO_2 in oil at room temperature, at around atmospheric pressure.

Impregnants are often degassed, or at other times their gas content is well below saturation. This has important consequences. When apparatus and/or insulation are filled with such impregnants at atmospheric pressure, and the apparatus is sealed afterwards and left unused, considerable drop of pressure can occur in the apparatus. This is due to the solution of the gases of the cavities occluded in the unsaturated impregnant.

When the cavity volume and amount of gas included on manufacture in the apparatus is known, these pressure drops can be estimated with the second equation, assuming that the gas in the cavities follows Avogadro's law, $p_c = c_c RT$, c_c being the gas concentration in the cavity, R the universal gas constant, and T the absolute temperature.

Where the included cavity volume is very small the pressure in the

apparatus can drop to very low steady state values. This is the case in power cables with impregnated paper insulation and low pressures of a few psi absolute have been observed repeatedly[1].

Conditions are different in sealed transformers, in which the gas-filled space is large and the pressure drops in the steady state caused by gas solution are smaller. Many parameters contribute in sealed transformers to the steady state pressure variations with load. How these variations can be calculated was shown in a thorough investigation by Franklin[2].

Steady states after solution occur rarely in practice, because this is obtained only when a load remains constant for days on an apparatus. The load varies usually in 24-hour cycles and impregnant, cavities, and their pressure are all the time in a transient state. When load is added, the temperature of apparatus increases causing thermal expansion. The thermal expansion of the impregnant is, by one order of magnitude, larger than that of the solid parts; and when the apparatus is sealed, the thermal expansion occurs on account of the volume of cavities and larger gas-filled spaces.

For this reason, but also owing to the temperature increase, the cavity pressure increases and in the same proportion also the gas concentration in the cavities increases. This by Henry's law, upsets the equilibrium with the gas concentration in the impregnant, and solution of cavity gas in the impregnant takes place. When load is taken off the apparatus, the reverse happens: the temperature decreases, the cavities increase in size, and gases come out of solution from the impregnant.

The problem is to ascertain the rate-of-the-solution processes. It will be seen that these processes are relatively slow. Solution of gases or the opposite process occurs all the time during operation, and cavity pressures are generally subjected to continuous variations.

The solution processes usually follow Fick's law of diffusion, and the rate of these processes can be calculated. According to Fick's law, the

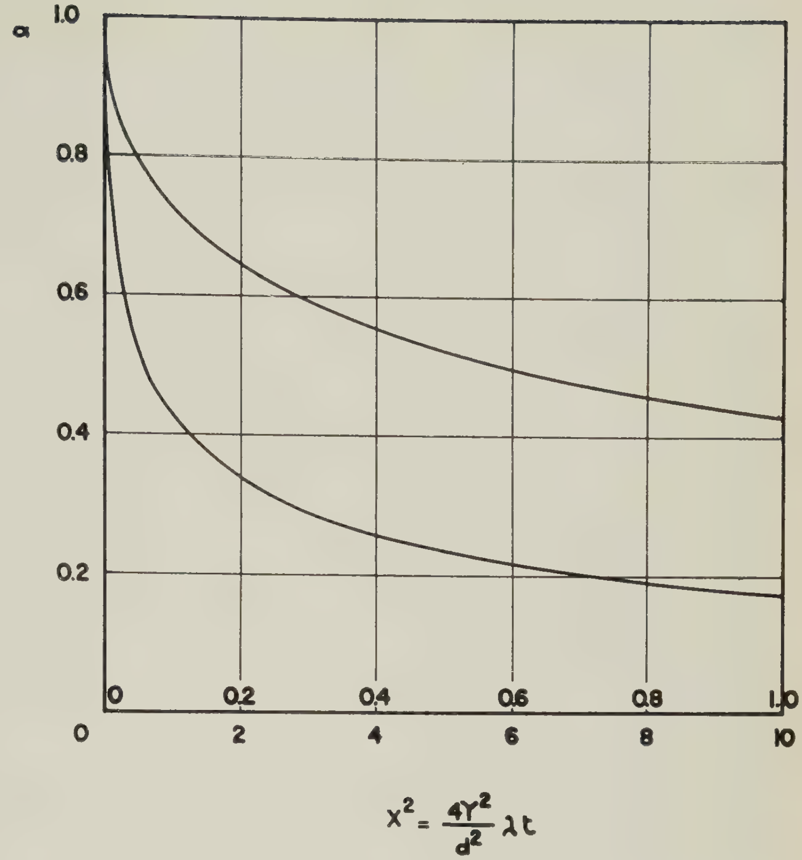

Figure 3, curve for the solution of the gas of a lens-shaped cavity in surrounding liquid. Upper curve, upper abscissae; lower curve, lower abscissae.

flow density of gas diffusing in the impregnant is $-\lambda$ gradient c_e, i.e., it is proportional to the diffusion coefficient λ of the gas dissolving in the impregnant and to the negative gradient of the gas concentration c_e in the impregnant.

The derivation of relations with Fick's law for the time dependence of the gas concentration in cavities is usually involved. Figure 3 shows such a relation for an idealized cavity, imagined to occur between infinite plane, parallel liquid surfaces, d apart, when the liquid is supposed to extend on both sides to infinity[3]. This case has a practical bearing, as it describes approximately processes around lens-shaped cavities whose dimensions are small compared with that of the impregnant.

The abscissa in figure 3 is the expression $x^2 = \frac{4\gamma^2\lambda}{d^2}t$, t being the time. The curve generally is applicable to cavities of varying thicknesses d and for varying solubility and diffusion coefficients. The ordinates α are defined by

$$\alpha = \frac{c_c - c_{cs}}{c_{co} - c_{cs}} = \frac{p_c - p_{cs}}{p_{co} - p_{cs}}$$

where c_{co} and p_{co} are cavity gas concentration and pressure at the beginning of the solution process, c_c and p_c the same in the transient state and c_{cs} and p_{cs} the same at the completion of the process in the state of equilibrium.

Much information is obtained from the curve. It can be seen that the solution (or the opposite) process is relatively rapid initially. The 50% stage, $\alpha = 0.5$, of solution is completed in a 12-times shorter time than the 80% stage, $\alpha = 0.2$ The time in which this latter stage is reached is obtained by reading for $\alpha = 0.2$, the abscissa $x^2 = 7.0$ and writing

$$7.0 = \frac{4\gamma^2\lambda}{d^2}t.$$

To realize the order of magnitude of duration t of these processes, let us choose for the parameters of the abscissae varying values of d, $\gamma = 0.075$

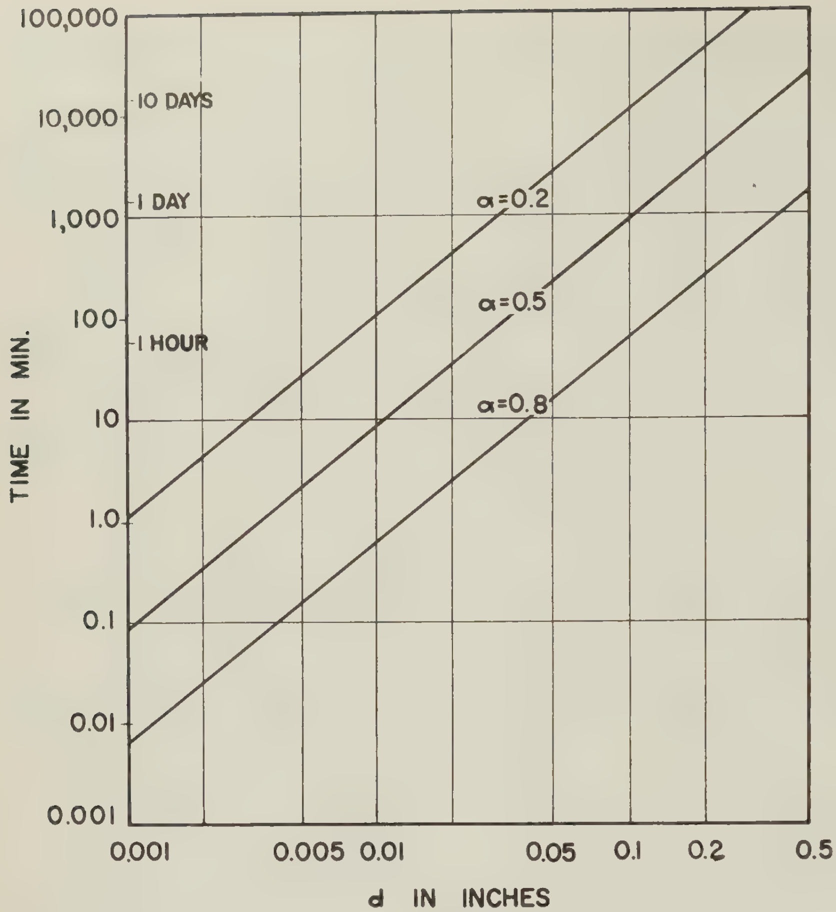

Figure 4, duration of solution process as a function of cavity thickness.

and $\lambda = 5 \times 10^{-6}$ inch^2/sec, which are figures characteristic for the solution of nitrogen in oil at operational temperatures of apparatus. With these data the family of curves of figure 4 was obtained, where time as function of cavity thickness d is given for the parameters α=0.2, 0.5 and 0.8 respectively, which correspond to stages of the solution process of 80%, 50%, and 20% respectively.

This figure shows the great differences in the speed of the solution processes. While the process is completed in about a minute for 0.001 inch thick cavities, it takes 10,000 times more time (several days) around a 0.1″ thick cavity. The same quadratic dependence exists also with respect to γ and because $\gamma = 1$ for CO_2 in oil, the solution process occurs

$$\left(\frac{1}{0.075}\right)^2 = 177$$

times more rapidly than with nitrogen and the ordinates of figure 4 have to be divided by 177.

Figure 4 cannot be applied directly to a sealed transformer. This case can be idealized by gas diffusing from space d/2 thick into a liquid of a finite extension. The solution process is therefore somewhat quicker than for solution into infinite space; still it is apparent that the process in a sealed transformer would go on for years if the transformer was not in operation and the oil did not circulate.

Small Cavities Vanish

Where the impregnant circulates solution processes occur much quicker than when the liquid is at rest. But in impregnated insulations proper (e.g., in condensers and power cables) circulation is small. In this case solution by diffusion has the consequence that the small cavities disappear. This important effect is produced by several mechanisms:

1) The insulation contains cavities of various sizes. According to figures 3 and 4 the gas from the small cavities dissolves rapidly; that from the large cavities slowly. The pressure in the large cavities becomes, therefore, larger than in the small ones. This pressure difference is transmitted by the impregnant, and the large cavities expand on account of the small ones. The pressure in the small cavities increases and the solution process continues until the small cavities have disappeared and the large cavities become enlarged by their volume. Surface tension acts also toward the disappearance of small cavities.

2) The effect of forces of gravity is similar, and small cavities at the bottom of containers filled with impregnant tend to disappear.

In addition to these effects, increase of the load and temperature of apparatus also can result in disappearance of cavities. This is especially the case in sealed apparatus with small cavity volume (e.g., power cables and condensers) where the thermal expansion occurs on account of the cavity volume. When the temperature is the largest permitted, usually only the largest cavities remain with their size much decreased but with increased gas pressure.

Cavitation Can Be Harmful

The disappearance of cavities is a favorable process for the life-time of the insulation, especially when care is taken that the large cavities (whose volume increases) are located outside the electric field. Such a process occurs after manufacture. But on cyclic operation, an opposite process occurs with equal frequency, and new cavities form in the insulation on cooling. Cooling is a harmful period to the insulation owing to corona in the numerous new cavities. These cavities form by the process of cavitation, which can be caused either by decrease of the mechanical pressure in parts of the insulation or by increase of the voltage.

Let us consider, first, reasons for the decrease of mechanical pressure and illustrate this by the behavior of a power cable on cooling. When a power cable has been on load for a long time only large cavities remain, such as under the sheath or in the conductor. The gases dissolved in the oil and in the cavities are in equilibrium by Henry's law, or in other words the oil is saturated with gas corresponding to a cavity pressure

p_{cs}. Shedding of the load causes cooling of the cable and contraction of impregnant and paper in the insulation. To fill the volume left by the contracting oil, the gas pressure p_{cs} in the cavities causes oil to flow into the insulation from sheath and conductor. This flow is opposed by viscous friction forces and in consequence the pressure in the impregnant of the insulation p_e becomes less than that at the sheath and conductor, where it is approximately p_{cs}.

As the quantity of gas dissolved in the impregnant is proportional to the pressure p_{cs}, the oil in the insulation becomes supersaturated with gas. Similar conditions of supersaturation can occur on cooling in any apparatus with impregnated insulations, and this state is conducive to cavitation.

Cavitation is of great interest not only in this field, but also in lubrication, physical chemistry, and hydraulic engineering. Yet cavitation is not completely understood[4]. It is well known that often only large degrees of supersaturations can induce cavitation, and the gases which enter the new, growing cavities are either gases coming out of solution, or vapors of the liquid. In the case of oil, vapors hardly play a role, because the vapor pressure of oil is extremely small at room temperature.

The reason that large supersaturations are necessary for cavitation is due to the fact that work is needed for the creation of the surface of new cavities. It is thought that the formation of new cavities depends upon the existence of small nuclei in the liquid, cavities forming relatively easily around these nuclei. The nature of these nuclei is not yet sufficiently clear but their existence is generally accepted.

The new cavities are of importance only if they can grow. The condition for this is simply obtained from the first equation by writing the inequality

$$p_c > p_e + \frac{4\sigma}{d}$$

meaning that the gas pressure in the cavity is larger than the sum of the opposing pressure of the impregnant and of that due to the surface tension. Such a state arises when the pressure p_e in the impregnant drops to very low values owing, for example, to flow of impregnant and/or when the cavity has already a sufficiently large diameter. The growing cavities are filled was gases coming out of solution from the impregnant.

The rate at which the new cavities grow can be ascertained only by involved calculations. Approximate estimates of growth times can be obtained by making use of Figures 3 and 4. Results of such calculations are given in the table for the duration of growth to 0.005 inch and 0.025 inch full size cavities[3]. Two cases are shown: in the first, oil is saturated with nitrogen at $p_{cs} = 2.5$ psia, but the pressure in the oil around the cavity is only $p_e = 0.5$ psia; in the second case $p_{cs} = 14$ psia and $p_e = 12$ psia.

Table of Growth Times.

Case $p_{cs}=2.5$ psia, $p_e=0.5$ psia

Full size of cavity, inch	Growth time, minutes
0.005	2¼
0.025	30

Case $p_{cs}=14$ psia, $p_e=12$ psia

Full size of cavity, inch	Growth time, minutes
0.005	450
0.025	10000

The table indicates the durations involved in the formation of new cavities; and when the pressure in the insulation is low, the process is rapid, and corona can start quickly. This points to an added disadvantage of low pressures in insulations; the other being the low corona inception voltage. Other results of calculations show that the cavity growth time is proportional to the square of the diffusion coefficient, hence cavity growth is by two orders of magnitude more rapid in apparatus filled with CO_2 than in that filled with nitrogen.

The newly formed cavities have mostly only a finite life-time. Once the cooling process is completed, the flow of impregnant stops and the pressure around the cavities increases. Then the processes reverse. Gases from the smaller cavities begin to dissolve in the impregnant, the volume of the larger cavities increases on account of the smaller ones, and ultimately the smaller cavities of the cooling process disappear. In accordance, the amount of corona decreases, and the loss angle of the insulation—which during cooling is large—becomes smaller again. This is well known in practice.

Cavities Due to Electric Field—Unexplained Phenomena

As previously stated, cavitation is also caused by increase of the electric field. These important phenomena have been known for many decades, but no satisfactory explanation of their cause is yet available. This kind of cavitation can be easily observed in strongly supersaturated oil at pressures of a few psia. Already on the application of an electrical field of less than 10 kv/cm bubbles can form in which no corona occurs. The electrical field adds its effect to that of pressure decrease in cooling apparatus and enhances the chances of cavitation. Of course the working voltage is constant, and only mechanical pressure changes are considered when estimating cavitation in an apparatus. But large voltage increases on phase faults or switching surges of long duration can lead to additional cavitation.

What are the means that prevent or decrease the likelihood of cavitation? The first of them is well known and is a thorough degassing of the impregnant. This procedure is widely practiced in sealed apparatus. The second is the prevention of large pressure drops caused by flow of impregnant through use of low viscosity impregnants. The third is the use of impregnants with the least density of nuclei for cavitation.

Little knowledge is available on the latter and that is empirical. Thus, it is known that highly refined oils cavitate much easier than less refined ones. It appears also that parts of the insulation, which were affected by corona, are apt to cavitate at relatively low supersaturations.

Conclusion

The picture which emerges from this short treatment on the behavior of cavities in impregnated insulations

is complicated. Calculations of the changes in individual cavities are so involved that usually only approximate solutions are available, as illustrated by figures 3 and 4 and the table. When the question arises, "How can the designer use the above for the estimate of corona in apparatus?", the answer suggested is, "both in a qualitative and a quantitative manner." The bases for the estimate are the Paschen curves for corona inception voltage V_i. The basic parameters determing V_i are the kind of gas, the size of the cavities, and the gas pressure, and these are the data which the designer can choose.

As shown, these parameters have interacting influences, and the choice of kind of gas, for example, does not influence V_i directly but results also in changes of the processes of gas solution and cavitation and in the corresponding gas pressures, leading thus indirectly to changes in V_i. Similarly, cavity size changes influence V_i directly and indirectly due to the rate of pressure changes in the solution and cavitation processes. These changes can be estimated with the help of the second equation and figures 3 and 4 (for details, reference is made to the literature [2,3]).

It was shown that in operation the three parameters are subject to changes all the time. The task of the designer should be to analyze these changes and estimate the limits of the changes in cavity sizes, pressures and kind of gas, and to alter the design until satisfactory corona inception voltages can be expected.

References

1) H. Halperin, "Load Ratings of Cable," AIEE Transactions, Vol. 58, Oct. 1939, pp. 535-56.
2) E. B. Franklin, "Sealed Transformers," Proc. IEE, London, Part A, Vol. 102, June 1955, pp. 265-78.
3) N. Klein, "Gas-filled Cavities in Solid-Type Cables, AIEE Transactions, No. 47, Apr. 1960, pp. 77-87.
4) P. Eisenberg, "Modern Developments in the Mechanics of Cavitation," Appl. Mechanics Rev., Vol. 10, March 1957, pp. 85-9.

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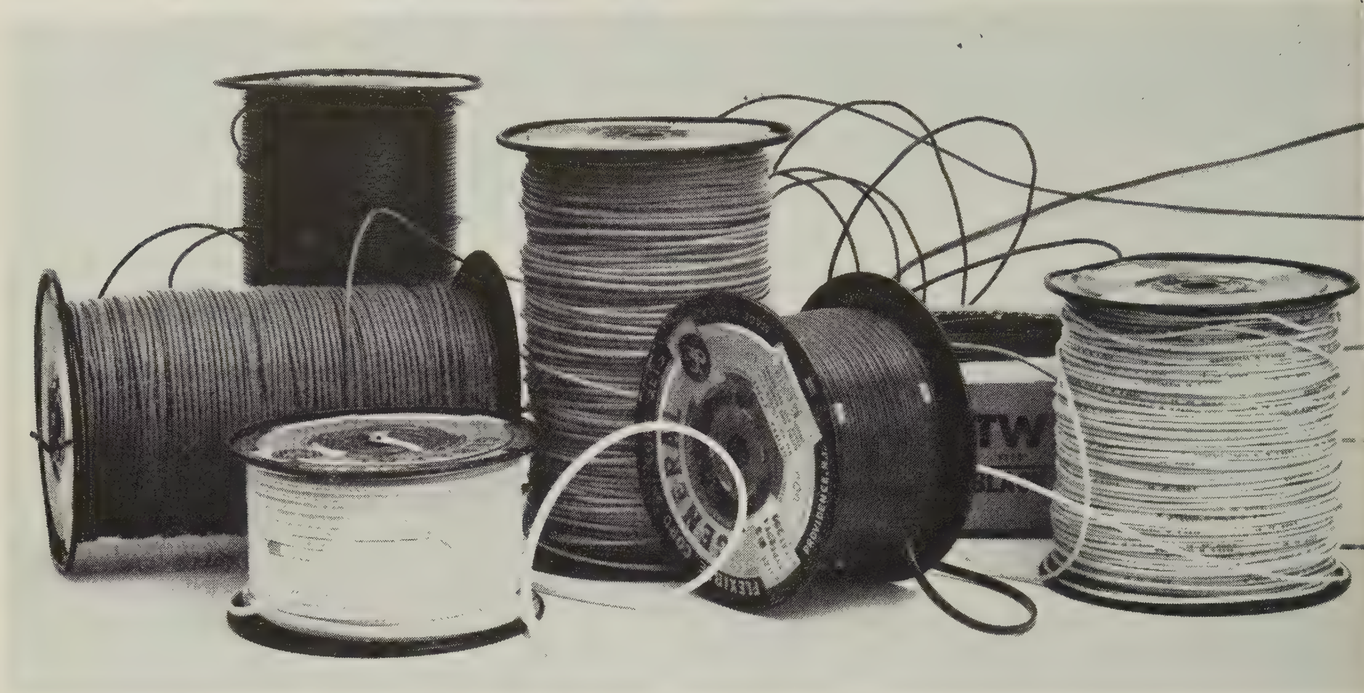

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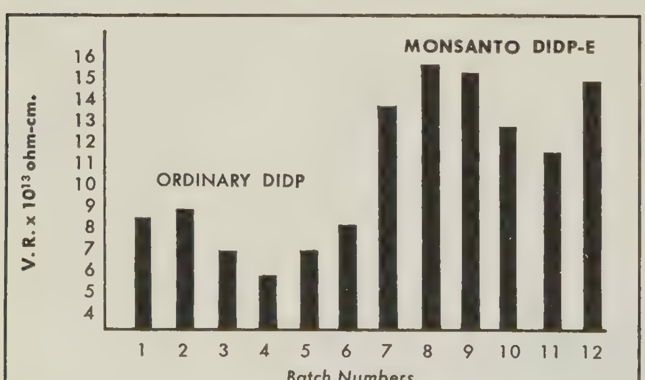

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	24 hrs. @ 50° C	100.0	180.0
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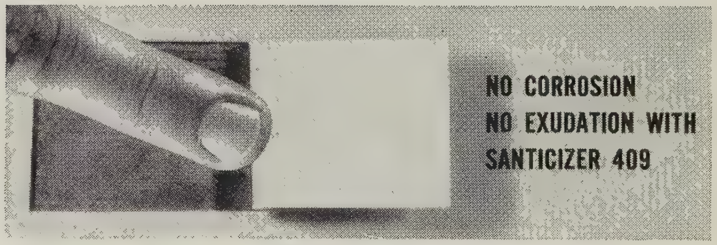
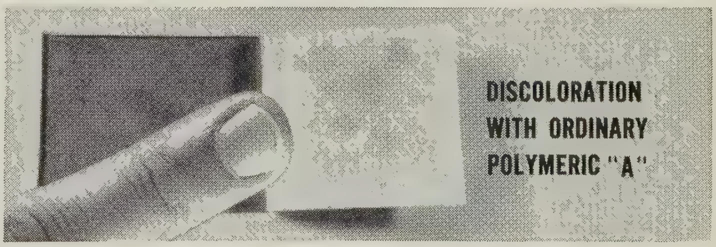
Insulation resistance, 1 day megohms/1000 ft. @ 50° C	3.84	2.45
Dry slab, ohm-cm. x 10^{12}	12.5	4.85

High humidity doesn't cause exudation of SANTICIZER 409 as it does with some other polymerics. (See photo.) Vinyl-covered copper electrodes were immersed in water for 12 weeks at 50° C. A reaction between the copper and the plasticizer in the vinyl shows as a greenish color on vinyl cover (above the copper conductor) which indicates exudation and poor compatibility. The photo at top shows no reaction for SANTICIZER 409 while the electrode with polymeric "A" shows considerable discoloration.





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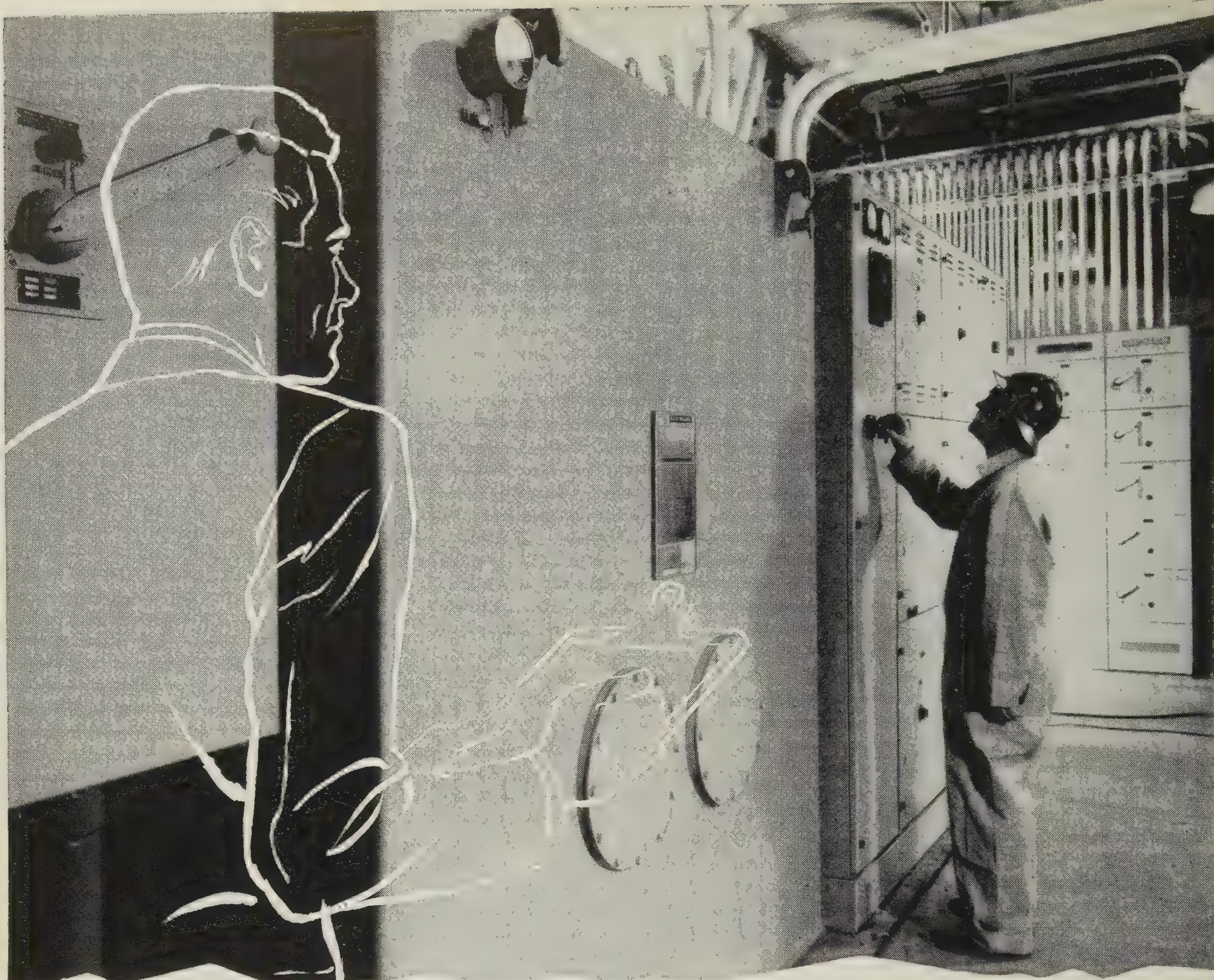

Trends in Insulating Materials and Application, Particularly High Temperature Problems

By H. Wood, Manager, Non-Metallic Materials, Rotax Ltd., London, England.

Looking in retrospect at the development of electrical insulating materials during the past 20 years, the first impression is one of utter confusion.

This applies particularly to the development of high temperature materials for aircraft electrical applications. The continuing improvements in design and performance of modern aircraft have created many problems, the foremost of which is to find materials which will withstand high temperatures and continue to behave satisfactorily, electrically.

To add to the difficulties, the materials, while being subjected to high temperatures and electrical and mechanical stresses, must also be capable of resisting attack from contaminants such as hot synthetic ester base engine lubricants and refrigerant gases.

However, closer examination shows that development has followed fairly clearly defined lines insofar as insulating materials have been repeatedly discarded and new ones substituted to keep pace with increasing temperature requirements. To illustrate this point, it can be said that prior to 1940, electrical equipment was not generally expected to operate at temperatures above 100°C.

Subsequently, however, with the race for superior military aircraft, temperature requirements were increased by jumps of about 50°C, up to the present day requirements which are likely to be as high as 400°C.

Table 1, B. S. I. Specification No. 2757
Classification of Electrical Insulating Materials

Class	Operating Temp. (max.)	Materials
Y (formerly O)	90°C	Cotton, silk, paper. Not impregnated.
A	105°C	Cotton, silk, paper. Suitably impregnated.
E	120°C	Combinations of materials which are thermally stable at 120°C for required period of time, say, phenolic impregnated paper, etc.
B	130°C	Combinations of glass, asbestos, mica, etc. Suitably bonded.
F	155°C	Glass, mica, asbestos, etc. bonded with materials which permit satisfactory operation at the specified temp. (155°C).
H	180°C	Silicone elastomer, mica, glass, asbestos, and combinations of these bonded with silicone resins.
C	180°C+	Porcelain, glass, mica, quartz, with or without an inorganic binder.

Table 2, Varnished Glass Fabric
Aged at 150°C, Effect on Thickness

	Initial Thickness, Mils	Aged 5706 Hours; Thickness, Mils	% Reduction in Thickness
Alkyd	4.5	3.0	33
Phenolic	4.9	3.0	39
Asphalt	5.31	3.4	36

In an attempt to meet these conditions, British Standards specifications have been modified as shown in table 1 on this page.

An examination of specification No. 2757 will show how materials

have changed from organics to inorganics with increasing temperatures.

For the purpose of assessing long term heat aging effects, a considerable amount of work has been done with various materials. Table 2 and figures 1 and 2 show typical results obtained when testing organic materials.

Note that 150°C was the maximum temperature at which these heat aging tests were carried out. There were no real requirements to exceed that temperature until after 1945, when operating temperatures were pushed up to 200°C. This meant that for aircraft electrical equipment new insulating materials had to be found and the earlier ones discarded.

Because of the widely varying applications, and in order to discuss specific requirements, it is necessary to define the various forms in which they are used.

These are as follows: 1) Round wire and strip conductor coverings. 2) Varnish or resin impregnated sheet insulation. 3) Impregnating varnishes and other impregnating mediums. 4) Resin bonded glass laminates. 5) Molding materials having mineral fillers. 6) Sleevings.

The subject of this work is the development of high temperature materials and for this reason, in considering the various applications as described above, no account will be taken of materials having maximum operating temperatures below 150°C.

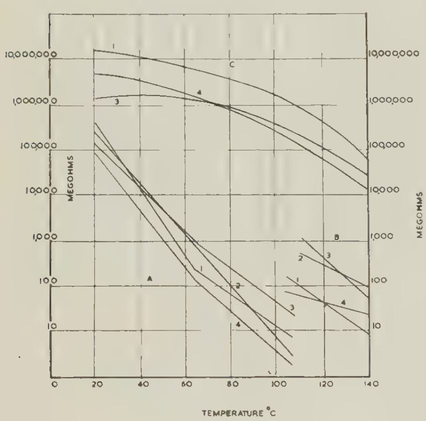

Figure 1, varnished glass fabric. Temperature effects on resistance of various materials (No. 1—alkyd, No. 2—bitumen, No. 3—asphalt, and No. 4—phenolic) aged as shown (A—no aging, B—after 163 hours at 110°C, and C—after 1743 hours at 140°C).

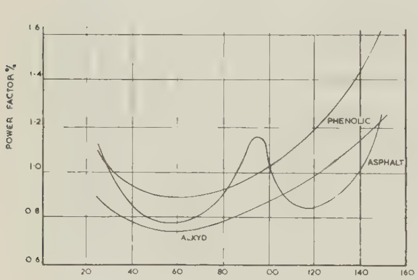

Figure 2, temperature effects on the power factor of varnished glass fabric .004" to .005" thick after 1743 hours at 150°C.

Round Wire and Strip Conductor Coverings

No real progress was made with these coverings until the introduction of polyvinyl acetal enamel modified with phenol-formaldehyde resin. Although the manufacturers originally placed a limit of 110°C on this enamel, it was consistently run at 150°C throughout the war years, and is being run at this temperature at the present time. After a period of about 10 years working at 150°C, the manufacturers relaxed their customary caution and raised the maximum operating temperatures to 130°C.

The introduction of silicones was the first real move towards raising the operating temperatures above 150°C and initial tests indicated that it might be possible to run silicone enamel covered conductors at 200-250°C.

However, in order to improve the mechanical strength and adhesion to copper, it was necessary to modify the silicones by the addition of alkyds. This reduced the operating temperature below the required figure and the gain in mechanical strength was not sufficient to justify the change. Subsequently, a new enamel covering was introduced and a useful life of 200°C was claimed for it. The material was a polyester glycerol terephthalate and repeated tests showed that the claim was justified.

The performance temperature-wise was at least 50°C better than polyvinyl acetal enamel but it was less flexible, and adhesion to copper was inferior. An added difficulty was failure to stand up to heat shock after "edge on" bending of strip conductors. Figure 3 shows an example of the effects of heat shock after being subjected to 150° for 60 minutes.

Conductors having mineral coverings such as glass and asbestos are now available, but these materials are limited to certain applications.

For instance, glass thread covering having no bonding medium is far too fragile for normal production handling, and therefore, it is necessary to employ bonding resin which immediately becomes the limiting factor from a temperature standpoint. Also, because of the ever present problem of weight restriction for aircraft applications, space factor is another serious limitation.

The same can be said of asbestos—which, in addition, is more hygroscopic. In the US considerable efforts have been made to overcome temperature problems, and it is possible to obtain from that country ceramic covered conductors having an outer covering of silicone elastomer or polytetrafluoroethylene (PTFE). These materials can be run at 250°C-300°C for useful periods of time but the applications must be carefully chosen. The ceramic covering is brittle, there is no adhesion to copper, and resistance to abrasion leaves much to be desired.

Having regard to all the conditions which must be satisfied; i.e., high temperature, chemical inertness in the presence of contaminants, electrical and mechanical strength, handling ability, and space factor, PTFE ap-

Figure 3, polyester terephthalate enamel, heat shock effect shown at "edge on" bend.

pears at the moment to be the material which most nearly meets these requirements.

Nevertheless, there are difficulties which must be overcome if full advantage is to be taken of it. PTFE is an organic high temperature thermoplastic. However, it does not have a true melting point as such. It vaporizes at 325°C, the rate of vaporization increasing with increasing temperature rise. In addition, "cold flow" characteristics must be accommodated.

Bearing these points in mind, this material must be suitably reinforced to reduce cold flow and should not be run at more than 270°C for extended periods, or 300°C for relatively short bursts. Even then it is essential to consider space factor when embarking on new designs embodying this type of insulation.

For applications above 300°C and up to 400°C, it is necessary to use anodized aluminum conductors and here again we are faced with difficulties. The anodic film is brittle and porous and so far there is no really satisfactory method of joining aluminum to copper. This applies particularly to aluminum conductors and copper and copper alloy commutator bars.

Varnish or Resin Impregnated Sheet Insulation

For aircraft electrical equipment it is generally necessary to specify insulating materials which are capable of satisfactory performances often well above 150°C. For this reason materials such as cotton, paper, silk, and natural rubber cannot be considered. Therefore, we are left with woven glass fabric, asbestos sheet, mica, and silicone elastomer.

When specifying woven glass or asbestos it must be kept in mind that in both cases it is necessary to apply a bonding medium which, of course, becomes the limiting factor on temperature. The choice of the bonding resin will depend on the end use temperature requirements.

For instance, epoxy resins and polyesters may be used up to 200°C, silicone resins up to 250°C, and PTFE up to 270°C or 300°C for short bursts. Silicone elastomer sheet may be used at 200°C to 250°C, and has the advantage of being flexible.

Mica, of course, may be run at very much higher temperatures, but is only slightly flexible and applications must be carefully chosen.

Impregnating Varnishes and Other Impregnating Mediums

The performance demanded of aircraft electrical equipment, particularly rotating parts, is so exacting that satisfactory impregnation is essential.

In addition to meeting temperature requirements, we have the added complication in rotating components of centrifugal force and, in the case of engine mounted equipment, contamination by hot synthetic engine oils and possibly refrigerant gases.

Because we are concerned only with operating temperatures of 200°C and higher, we are again limited to polyesters, epoxies, silicones, and PTFE. In order to achieve the best possible performance, vacuum impregnation is necessary, and when epoxies or silicones are used, the impregnating and baking may be carried out in accordance with the supplier's recommendations.

Epoxies and polyester resin varnishes are satisfactory up to 200°C for useful periods and silicones up to 250°C. Care must be taken to insure that the above contaminants are excluded from equipment having silicone varnish impregnation.

More recently, a considerable amount of work has been done in the development of PTFE as an impregnant.

The introduction of new impregnants presents many problems and care must be taken to insure that everything possible is known of the disadvantages of the materials in question.

In considering PTFE, we knew that the problem of "cold flow" had to be overcome; also, being fibrous, coagulation was certain to take place during the vacuum impregnation process. In addition, because fluorine gas is given off at the required sintering temperature, adequate ventilation had to be provided.

Figures 4, 5, 6, 7, and 8 illustrate different applications and the measure

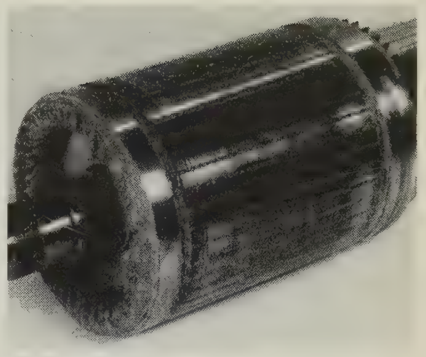

Figure 4, aircraft jet engine starter motor armature, PTFE-glass-mica insulation. 170 hours at 270°C.

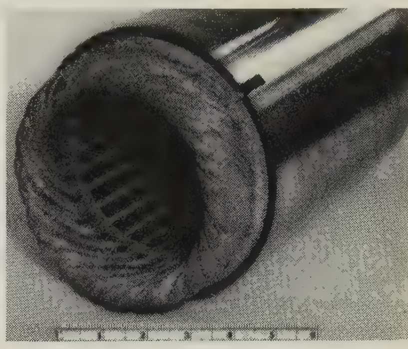

Figure 5, nuclear stator for nuclear submarine, PTFE-glass-mica insulation. Max. operating temperature, 300°C.

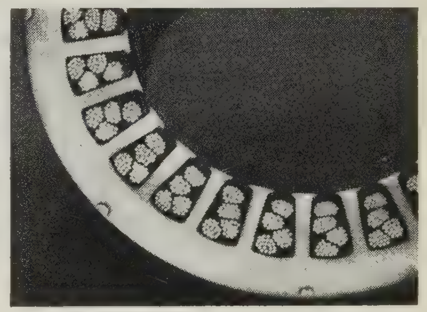

Figure 6, section through nuclear stator showing depth of PTFE vacuum impregnation.

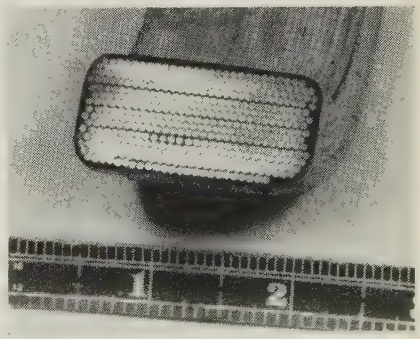

Figure 7, section through stationary field coil, PTFE-glass-mica insulation. Vacuum impregnation.

Figure 8, stator for industrial application, PTFE-glass-mica insulation.

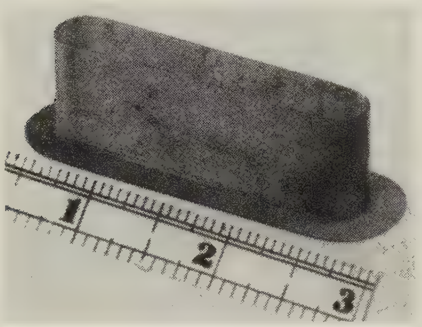

Figure 9, pole shoe insulator, epoxy resin bonded glass laminate.

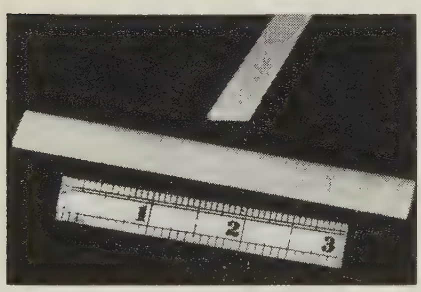

Figure 10, armature core slot box insulator, polyester resin bonded glass fabric. Note central separator in top end-view.

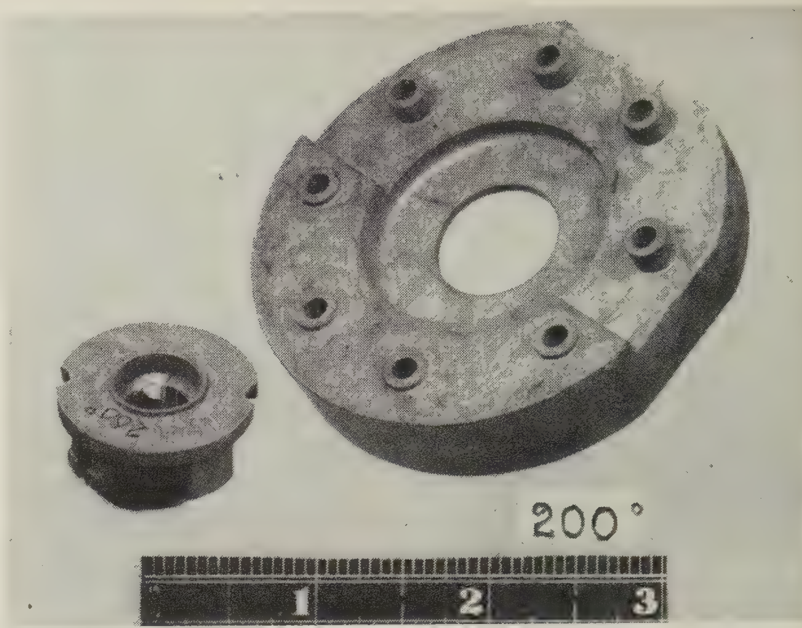

Figure 11, molding in glass-filled modified phenolic. Aged at 200°C for 150 hours. Badly blistered.

Figure 12, molding in glass-filled alkyd aged at 200°C for 150 hours. Condition satisfactory.

of success which has been achieved with PTFE impregnation.

Note that if it is decided to employ PTFE impregnation, it must be remembered that the sintering temperature is 360°C—370°C and care must be taken that other materials which may be used in the insulating system will not be adversely affected during the sintering process. This also applies to any metal in the assembly.

Resin Bonded Glass Laminates

In manufacturing resin bonded glass laminates for high temperature applications, the same restrictions apply to the choice of resins as previously stated.

The number of layers of glass varies according to specified thickness and the laminated material is produced by bonding the layers of woven glass fabric together by heat and pressure and using the specified resin.

The uses of these materials are many and varied. To name a few, there are end insulators for d-c rotating armatures, switch base insulators, transformer and coil bobbins, brush gear insulators, etc.

More recently, there has been an increasing demand for special forms of resin bonded glass insulators, such as armature and stator slot insulators, and preformed pole shoe insulators. These insulators are being produced by what is known as the "wet lay-up" method with specially designed tools and mandrels. It has

been found that by carefully controlled methods, limits of .002″ can be maintained on material thicknesses varying between .010″ and .031″. Examples of components produced from specially formed laminates are illustrated in figures 9 and 10.

Molding Materials Having Mineral Fillers

In the search for high temperature molding materials, many problems have had to be overcome, including molding tool design and molding techniques; i.e., press speeds, cure times and temperatures, shrinkage, and cracking around metal inserts. In addition, in order to achieve the highest possible stability under extremes of service conditions, much work has been done in post baking.

Temperature again limits the choice of materials. The ones most generally used are alkyds, epoxies, silicones, and mica filled glass.

Alkyds and epoxies are used with a fiber glass filler and useful life at 200°C is obtained. The plastic yield performance of epoxies at high temperatures is inferior to that of alkyds, and therefore, alkyds are preferred for applications where mechanical strength is of major importance.

Glass filled silicone moldings may be used at temperatures up to 250°C, but care must be taken to avoid contamination by hot synthetic engine oils, and because of the inherently poor bond, mechanical strength is not always adequate. Also, the cost is high, shelf life is relatively short, and molding processes are complicated.

Moving towards higher temperature requirements, we are compelled to consider inorganic materials and the best available at present is a combination of glass and powdered mica. This material is pelleted and sintered at 750°C and molded in tools which are heated to 350°C.

Because the expansion coefficient is similar to metals, it is particularly suited for carrying inserts. However, the material is brittle and heavy, and for aircraft use moldings should be small and of regular cross section.

Typical moldings and temperature effects are shown in figures 11, 12, 13, 14, and 15.

Sleevings

Sleevings, in addition to having to satisfy electrical, mechanical, high temperature, and resistance to contamination requirements, must also remain flexible over service working temperature ranges.

Early efforts to meet high temperature needs brought about the introduction of braided glass sleeving which, because of the lack of electrical and mechanical strength, had to be impregnated with a conventional organic varnish, modified alkyd being a typical example.

At heat aging temperatures of 150°C and higher, this sleeving became brittle and frequent cracking occurred. No real progress was made with this problem until silicone elastomer sleeving became available.

The tear strength of silicone elastomer or "rubber" is not equal to that of other synthetic rubbers or natural rubber, but this can be largely overcome by reinforcing with glass braid. Silicone elastomer sleeving will remain flexible at temperatures down to —60°C and up to a maximum safe working temperature of +250°C.

When specifying this material, consideration must always be given to the question of contaminants. If for any reason silicone elastomer cannot be used, PTFE sleeving is available in two forms: a) extruded, and b) glass braid bonded with PTFE dis-

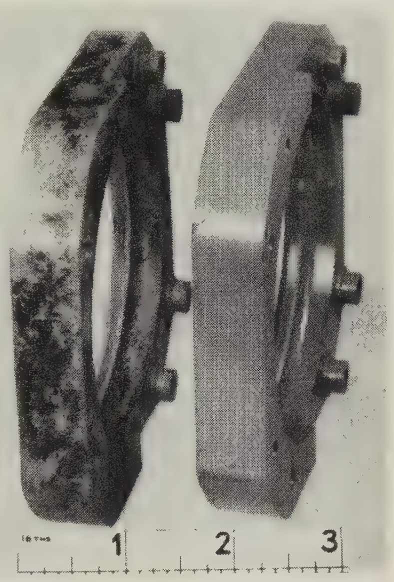

Figure 13, glass filled-alkyd molding as received from mold and after aging at 200°C for 500 hours. Although badly discolored, it is still serviceable.

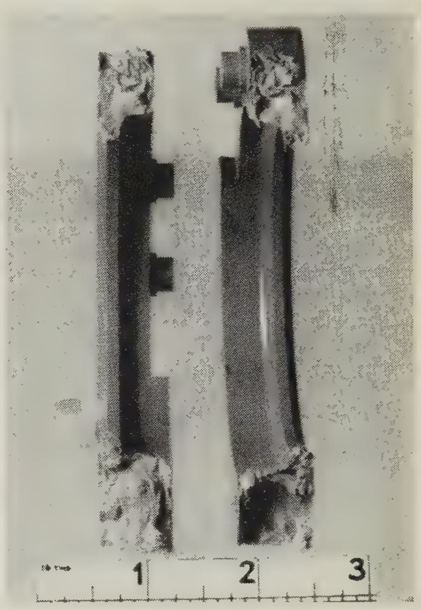

Figure 14, glass filled alkyd molding as received from mold, broken to show formation of glass fiber filler.

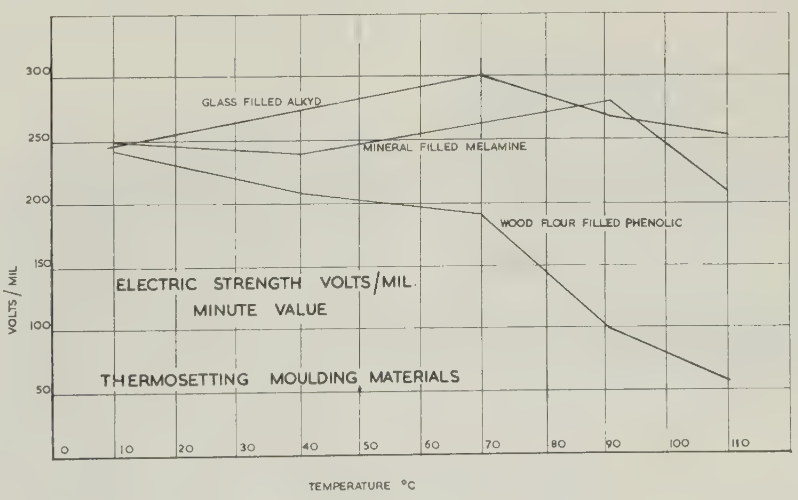

Figure 15, temperature effects for some thermosetting molding materials.

persion. The temperature range is somewhat wider than that of silicone elastomer, but both versions are much less flexible and more difficult to manipulate in confined spaces. However, PTFE resists attack by hot engine oils and all organic solvents.

Future Requirements

The foregoing brief account draws attention to a few of the problems which have been encountered in arriving at present conditions. In considering future trends, we are confronted with the problem of finding materials capable of useful operation up to 400°C. This immediately excludes the use of all known organic materials.

Conductor Coverings

An attempt has been made by London Electric Wire Company and Smiths Ltd. (England) to extrude an aluminum covering onto copper wire, the object being to anodize the aluminum, thus forming a mineral insulator on the copper.

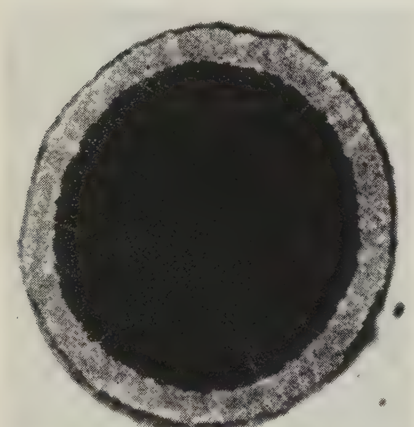

Figure 16, anodized aluminum clad copper conductor. Diameter of copper, .0076" Photograph 265 X. Courtesy of London Electric Wire Co. and Smiths Ltd.

Remarkable consistency of thickness of covering was achieved, but during extrusion the copper became work hardened and brittle and the anodic film was porous and brittle. Figure 16 shows a cross section of the conductor.

Molding Materials

Until quite recently the material most suited for operation at 400°C and higher temperatures was aluminum oxide.

Almost any design of component can be produced by preforming and sintering. The sintering temperature is in the region of 1650°C.

The main difficulties with this material are shrinkage during sintering and hardness and lack of flexibility after sintering. In the sintered condition, machining is virtually impossible except by diamond wheel. Although very little of this material has been used for aircraft electrical equipment, it is finding an outlet in nuclear applications. Figure 17 shows a small switch box which is being produced in limited numbers for operation at 500°C.

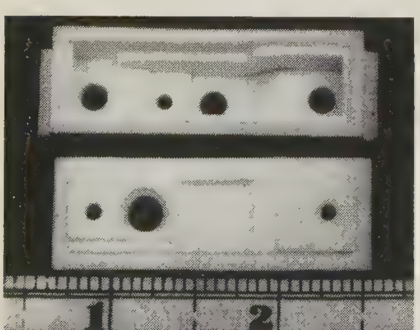

Figure 17, switch box and cover of preformed alumina sintered at 1650°C for nuclear application. Operating temperature is 500°C.

The latest molding material to come up for evaluation is an asbestos filled phosphorous resin, which it is understood has been developed in the US. It is molded at 300°C and preliminary tests show that it appears to be unaffected after being subjected to 400°C for 7 days. In the molded condition it is black in color and has a distinctly mechanical ring. Electrical breakdown and water absorption tests are at present disappointing.

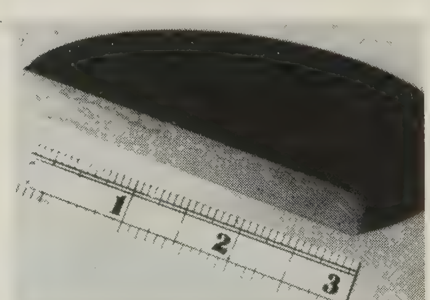

Figure 18, phosphorous resin asbestos filled disc molded at 300°C. Section shows crack caused by trapped gases.

However, it must be mentioned that a really satisfactory molding technique has not yet been developed in England, and initial test results could thus be misleading. At the molding temperatures of 300°C there is considerable gassing and fuming which prevent the molding from becoming really consolidated. This could well affect water absorption and electric strength. Modification to the ventilation of the tool will probably help in this direction.

Figure 18 shows the mark of the cavity created by trapped gas.

Impregnants

In considering impregnants for operation at more than 400°C, a completely new approach must be made as it appears that success is most likely to be achieved with low melting point glass having a gradual softening temperature range and with a suitable filler.

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Summary

In this article an attempt has been made to show some of the problems which have had to be overcome in developing insulating materials for aircraft high temperature electrical equipment.

Attention is also drawn to the problem of finding materials capable of working at the anticipated higher temperatures of the not too distant future.

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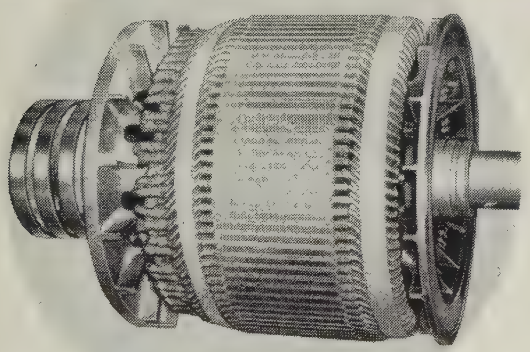

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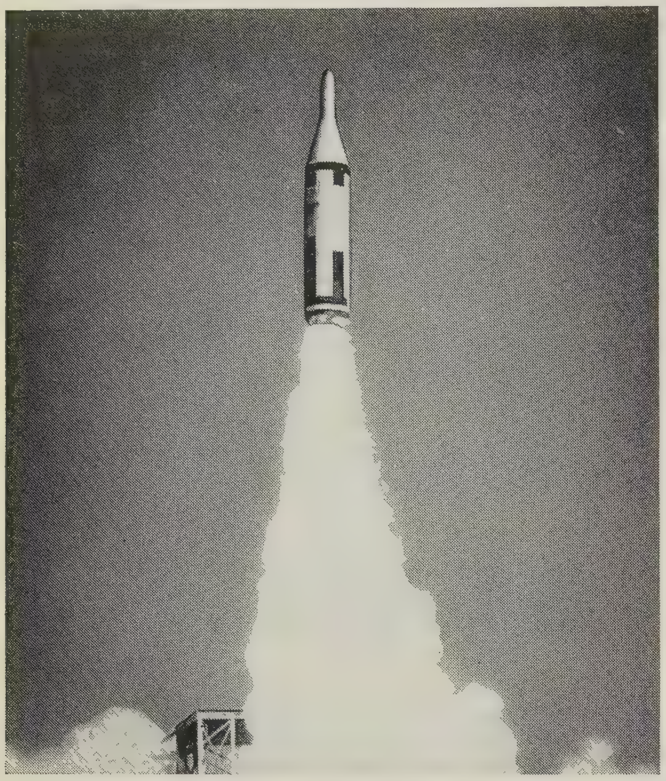

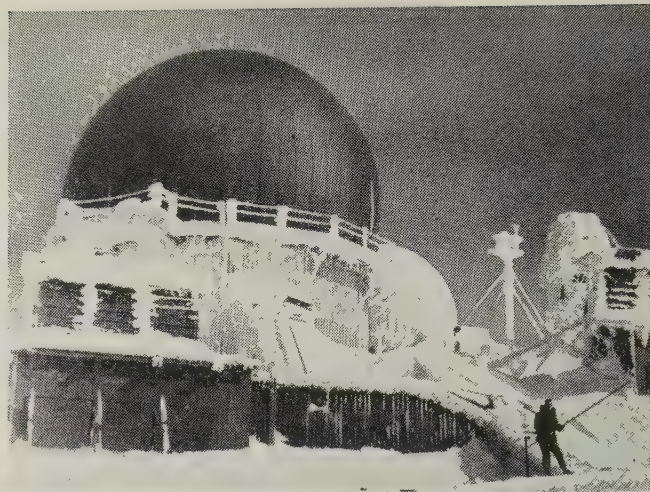

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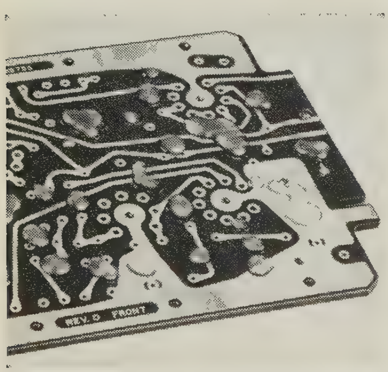

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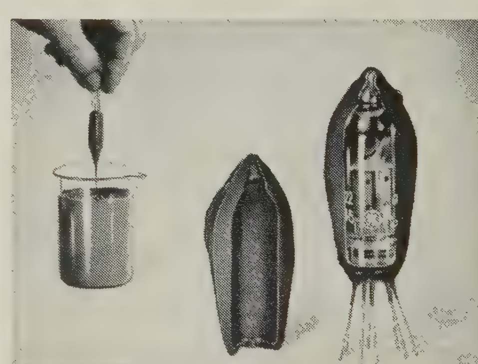

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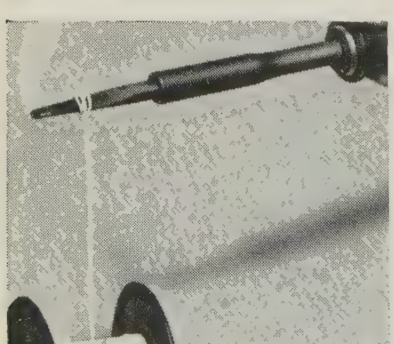

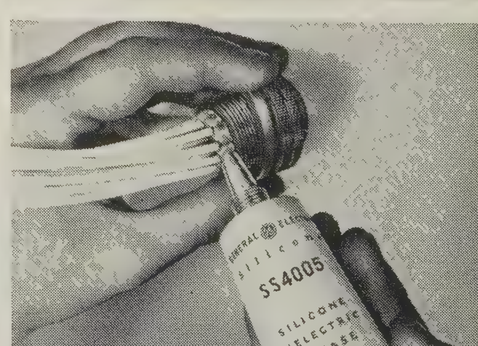

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Solvent Resistance of Enamelled Wire

By Karl Schmidt, Dr. Beck & Company GMBH, Hamburg, Germany.

The question of the suitability of enamelled wire for the construction of sealed refrigerator units is coming more and more to the fore. Two factors are of particular importance in assessing the suitability of a given enamelled wire: the nature of the enamel solids, which decides the properties, and the method of application.

By judicious choice of application and baking conditions, it is possible to develop an optimum resistance of the enamels to the solvents. In the course of this article, we shall try to demonstrate what properties are inherent in the various enamels and to what extent these may be modified by a variation in application and baking conditions.

Types of Wire Enamel Studied

Altogether, four different types of wire enamel were investigated.

1) A terephthalic acid polyester enamel.

2) A Desmodur/Desmophen (DD) enamel, the ester component of which has a relatively high phthalic acid content.

3) A superpolyamide-DD-phenolic resin.

4) A polyvinyl formal-phenolic resin combination, similar to an American formulation.

The test wires were first coated under optimum conditions. Next, the oven temperature was, in one case, raised by about 30°C and, in another, lowered by about 30°C—the drawing-off speed remaining about the same. One series was given a thin coat according to the German Specification DIN 46453, sheet 1, while a heavy coat was applied in the other series:

	Thin coat	Heavy coat
up to 1 mm dia.	$50\mu\pm10$	$85\mu\pm20$
0.3 mm dia.	$25\mu\pm5$	$43\mu\pm10$

A great variety of methods have been suggested for the removal of the enamel for determinations of the extract, thickness of coating, etc. In most cases, phosphoric acid is used for stripping. Other methods specify the use of formic acid.

According to BSS 1844:1952, sulfuric acid is used. Table 1 shows the effect of these acids, and we note that increasing amounts of copper go into solution as the time of contact with the acid increases.

The safest method, in our opinion, appears to be "burning off" followed by quenching in methanol. Bare wire and stripped wire (> 0.2 mm dia.) both gave 0% loss as a well reproducible figure. It is, therefore, particularly important in extract determinations to pay attention to possible sources of error arising from the stripping of the enamel coating.

Toluene-Methanol Extraction (Cold)

Table 2 gives the results obtained for toluene-methanol extractions, which were carried out in duplicate.

Table 1—Treatment of Copper Wire with Acids (Percent Weight Loss)

Treatment Time	Phosphoric 85% 1 mm	Phosphoric 85% 0.3 mm	Formic 98% 1 mm	Formic 98% 0.3 mm	Sulfuric 96% 1 mm	Sulfuric 100% 1 mm
3 Secs.	0.007	—	—	0.016	5.6	1.46
			Increase			
10 Secs.	0.007	0.012	+0.003	0.008	13.7	12.47
30 Secs.	0.008	0.011	+0.004	0.026	20.2	31.8
60 Secs.	0.012	0.097	+0.004	0.024		
3 Mins.	0.016	0.32	+0.001	0.027		
10 Mins.	0.038	2.39	+0.002	0.021		

Burning and quenching in Methanol: No loss in weight of copper for bare wire and enamelled wire.

Table 2—Percentage Values for (Cold) Toluene-Methanol Extraction

		Thin Covering Toluene	Thin Covering Methanol	Thin Covering Total	Heavy Covering Toluene	Heavy Covering Methanol	Heavy Covering Total
Terephthalate	light	0	0	0	3.1	0	3.1
	normal	0	0	0	1.19	0.18	1.37
1 mm	dark	0.25	0	0.25	0.73	0	0.73
DD-Enamel	420°C	0	2.0	2.0			
(pure)	450°C	1.3	0.98	2.28	tends to cold craze		
1 mm	480°C	3.57	3.65	7.22			
Polyamide	light	0	1.2	1.2	0	2.1	2.1
DD-Phenolic	normal	0	0	0	0.65	1.9	2.55
Resin, 1 mm	dark	4.5	6.1	10.6	1.9	3.48	5.38
Polyvinylformal-Phenolic Resin, 1 mm	normal	4.75	0	4.75		—	
Terephthalate	light	0	0	0	0	0	0
	normal	0	0	0	0	0	0
0.3 mm	dark	0	0	0	0	0	0
Polyamide	light	2.3	3.0	5.3	0.74	5.5	6.24
DD-Phenolic	normal	3.2	1.2	4.4	0	0.6	0.6
Resin, 0.3 mm	dark	2.6	4.6	7.2	0.5	2.06	2.56

The results for the first four materials listed are for 1 mm enamelled wire and those in the last two listings are for 0.3 mm wire. Only some of the thin wire was tested. The data for the thin coats are given on the left and that for heavy coats on the right. We see that in the case of a thin coat of terephthalate enamel there is no attack from either the toluene or methanol, when the enamel is baked under normal baking conditions or under conditions resulting in a light color.

Enamel baked to a dark color shows some attack by toluene but is still unaffected by methanol. A somewhat different situation is encountered with heavy-coated wire. The values of the extract are higher. We find quite often that a heavy-coat is more sensitive to all kinds of attack than a thin-coat enamel.

It is interesting to note that the extract values of heavy-coat enamels decrease with increasing baking temperatures. This applies particularly to the toluene extract. We find quite generally for terephthalate enamel that, if it is at all affected by solvents as a result of incorrect baking conditions, it tends to be attacked more by aromatic hydrocarbons—a phenomenon which has its origin in the aromatic character of terephthalic acid. The second horizontal section contains the results of the investigations of DD enamel, which consists only of ester and isocyanate.

Since the condition of the baked DD enamel cannot be judged by color, we have reported the actual baking temperatures. Raising the baking temperature of the thin-coat enamel results in an increase of both the toluene and the methanol extracts. It is known that, when DD enamels—which are by nature sensitive to incorrect baking conditions—are baked at too high a temperature, they start to decompose in the way a macromolecule depolymerizes. The decomposition products often behave like plasticizers and are, therefore, extracted by solvents.

Unfortunately it was not possible to test a heavy-coat enamel because of its marked tendency to craze (cold check). The third horizontal section contains results for the very much used combination of polyamide with DD and phenolic resin. The relatively high numerical value of the toluene and methanol extracts of enamel baked to a dark shade is probably due to the DD component. Otherwise, we noticed, especially in the case of heavy-coat enamels, a greater sensitivity to alcohols (polyamide component). Unfortunately, the only type of polyvinyl formal-phenolic resin enamelled wire at our disposal was that baked under normal conditions.

We noticed a relatively high sensitivity to aromatic hydrocarbons and a good resistance to methanol. The situation in the case of the 0.3 mm enamelled wire is the same as for the 1 mm wire, with the possible exception of terephthalate, which shows an increased resistance to extraction. The polyamide combinations, on the other hand, yield values analogous to those for the 1 mm wire.

Table 3—Percentage Values for Methanol Extraction (Hot)

		Thin Covering		Heavy Covering	
		10 min.	24 hrs.	10 min.	24 hrs.
Terephthalate	light	+0.7	0	+0.7	0.075
	normal	0.1	0.32	+4.1	0.08
1 mm	dark	0.11	0.10	+0.11	0.03
DD Enamel	420°C	constant weight			
	450°C	not attained		tends to cold craze	
1 mm	480°C				
Polyamide-	light	softened		softened	
DD-Phenolic	normal	softened		softened	
Resin, 1 mm	dark	7.2	7.2	softened	
Polyvinylformal-Phenolic Resin, 1 mm	normal	3.3	3.3	—	—
Terephthalate	light	0.06	0.06	+0.08	0.11
	normal	0.26	0.15	+0.18	0
0.3 mm	dark	0.27	0.2	+0.1	0
DD-Enamel	420°C	+0.36	0.15		—
0.3 mm	450°C	+1.2	0.27	—	—
Polyamide-DD-	light	5.16	5.23	4.2	5.0
Phenolic Resin,	normal	6.3	5.51	4.35	4.35
0.3 mm	dark	9.25	8.23	5.3	5.3

Hot Methanol Extraction

Here again we have divided the enamels into thin and heavy-coated types. In table 3, the left column under each heading gives the results obtained under drying conditions as specified in the American method; i.e, 10 minutes at 150°C; while the right column refers to drying for 24 hours at 150°C.

About 50% of the samples tested gave an increase in weight on drying for 10 minutes at 150°C. Only in the case of the polyvinyl formal is there no difference between drying for 10 minutes or for 24 hours. We will, therefore, base our evaluation of the test results on the 24-hour drying period.

Terephthalate thin-coat enamel gives an extract figure between 0 and 0.32%. The higher figure obtained for the thin-coat enamel film is somewhat surprising and difficult to explain. It would, therefore, be advisable to repeat the test. The general level of the values, on the other hand, is quite low. We know that terephthalates are noted for their alcohol resistance over a wide range of baking conditions. Apart from this figure of 0.32% we do not find any significant differences for any set of baking conditions for either thin or heavy enamel films.

The DD enamel could not be included in the results because of the tendency of the heavy-coat enamel film to craze and the extraordinary solvent retention shown by the thin-coat enamel, which could not be dried to constant weight even in 24 hours. Drying for periods longer than 24

hours at 150°C may have to be regarded as aging, and the additional weight losses could then be due to thermal treatment.

In the case of polyamide combinations, we noticed (as is already known) that they are particularly sensitive to hot alcohol. The boiling methanol softens the enamel so much that testing becomes impossible. Only the thin-coat enamelled wire, baked to a dark shade, was still measurable. The more favorable behavior of this enamel may be explained as being due to the more advanced state of cure of the phenolic resin and its fortifying effect on the structure of the enamel. The polyvinyl formal combination has already been discussed. It is worth noting that it gives a surprisingly high extract figure. The extract figures obtained for 0.3 mm wire are comparable with the values for 1 mm terephthalate-enamelled wire.

The values of DD enamel are surprisingly very low. We did, however, mention that we chose an ester based on a high proportion of phthalic acid. Such esters are known to have good resistance to alcohols. In addition, the tendency to crazing of the thinner gauge wire is also lower. Hairline cracks may, however, cause the absorption of solvent into the enamel layer by capillary effect.

The values for polyamide combinations are lower for 0.3 mm wire than for 1 mm wire. This shows that adequate cure is possible for the thinner layers. Even these values do, however, remain open to doubt in an assessment of the suitability. A comparison of the values obtained in the methanol extraction for the thin and heavy enamel films shows no significant differences.

Table 4—Percentage Values for Trichlorethylene Extraction (Bosch Method)

		Thin Coat	Heavy Coat
Terephthalate	light	1.07	1.75
1 mm	normal	0.89	1.22
	dark	1.16	1.15
DD-Enamel	420°C	0.29	1.02
1 mm	450°C	0.33	0.24
	480°C	1.04	0.36
Polyamide-DD-	light	0.82	1.31
Phenolic Resin	normal	0.76	0.76
1 mm	dark	2.51	2.38
Polyvinylformal-Phenolic Resin 1 mm	normal	4.33	—
Terephthalate	light	1.07	0.87
0.3 mm	normal	0.98	0.60
	dark	1.79	1.63
DD-Enamel	420°C	0.65	—
0.3 mm	450°C	1.32	—
Polyamide-DD-	light	0.93	1.26
Phenolic Resin	normal	3.89	1.35
0.3 mm	dark	4.99	2.41

Table 5—Freon-12 Extraction Percentage Values

		Thin Coat	Heavy Coat
Terephthalate	light	0	0
	normal	0	0
1 mm	dark	0	0
DD-Enamel	420°C	0	0
	450°C	0.16	0.07
1 mm	480°C	0.24	0.13
Polyamide-DD-	light	0.23	0.07
Phenolic Resin	normal	0.17	0.09
1 mm	dark	0.03	0.14
Polyvinylformal-Phenolic Resin, 1 mm	normal	0	—
Terephthalate	light	0	0
	normal	0	0
0.3 mm	dark	0	0

Trichlorethylene Extraction (According to Bosch)

In table 4, the spread in the values for terephthalate thin and heavy enamel films—within the limits set by light, normal, and dark—is relatively small. Thin-coat enamel, baked under normal conditions, has a trichlorethylene extract of 0.89% and is, therefore, well within the useful range.

The DD enamel has surprisingly low trichlorethylene extract values. An abrupt change is noticed for the enamel baked at 480°C, indicating that the enamelled wire has been overcured. In comparison, the highest extract value for the heavy-coat enamel was found at the lowest baking temperature—a clear indication that the enamel was under-cured. For the heavy-coat enamel there is, therefore, a general shift of the level of baking temperatures in the direction of higher temperatures.

We shall see from other examples that the tolerance of DD enamel for deviations in baking conditions, too, is somewhat larger for the heavy-coat enamel; i.e., there is a broadening of the range of baking conditions with increasing thickness of enamel.

Polyamide combinations, too, have quite useful extract values, with the exception of the "dark" baked enamelled wire.

The results of the trichlorethylene extraction are, therefore, the very opposite of those of the methanol extraction. Polyvinyl formal enamel has a high extract value of 4.33%.

Terephthalate-enamelled wire of 0.3 mm diameter yields extract values similar to those of the 1 mm wire with

Table 6—Comparison of Percentage Value Results of the Four Extraction Methods

Wire Dia., 1 mm	Toluene-Methanol Thin Coat To.	Toluene-Methanol Thin Coat Me.	Toluene-Methanol Heavy Coat To.	Toluene-Methanol Heavy Coat Me.	Methanol Thin Coat	Methanol Heavy Coat	Trichlorethylene Thin Coat	Trichlorethylene Heavy Coat	Freon-12 Thin Coat	Freon-12 Heavy Coat
Terephthalate	0	0	1.19	0.18	0.32	0.08	0.89	1.22	0	0
DD-Enamel	1.3	0.98	—	—	no loss in wt.	cold checked	0.33	0.24	0.16	0.07
Polyamide Combination	0	0	0.65	1.9	softened		0.76	0.76	0.17	0.09
Polyvinyl-formal Combination	4.75	0	—	—	3.3	—	4.33	—	0	—

the exception of the "dark" sample which has a higher value than expected. Because of lack of time, we did not extend our investigations to heavy-coat enamelled wire of 0.3 mm diameter.

The polyamide-DD-phenolic resin combination enamel is even more sensitive to over-curing in the case of the 0.3 mm wire than it was for the 1 mm wire.

Freon-12 Extraction

Table 5 gives the results of Freon-12 extractions carried out according to the method of Steinle. No material is extracted from terephthalates for the entire range of baking conditions.

In the case of DD enamel the extract value increases with increasing baking temperature for both thin and heavy coats. In this instance, too, it is to be assumed that decomposition products resulting from overheating are being dissolved in the course of the extraction. The Freon-12 extraction, too, shows that the heavy coat has a wider permissible range of baking temperatures.

The polyamide combination behaves in just the opposite way, the extract value becoming less as the baking temperature is increased. The effect of the DD is presumably cancelled out by the additional rigidity imparted to the structure by the progressive curing of the phenolic resin. This characteristic is especially evident in the thin coat, whereas for the heavy coat the amount of extracted material remains very nearly constant, with the exception of the dark, over-baked sample which gives a somewhat higher figure.

The one and only sample of polyvinyl formal examined showed very good resistance to Freon-12. Of the 0.3 mm wire, only the terephthalate was tested; as for the 1 mm wire, no extract was recorded for the entire range of baking conditions.

Results

Table 6 summarizes the results of the four extraction methods for comparison, taking in each case the 1 mm wire—with thin and heavy coats of enamel—baked under normal conditions. The values for the terephthalates present a very good picture. The trichlorethylene extract values for the heavy coat are, however, a little too high. It remains to be tested whether the baking conditions applied are the optimum conditions for the wire.

The DD-enamel is rather sensitive to the toluene-methanol extraction test and fails completely as a heavy-coat enamel because of crazing. Extraction with hot methanol, too, is unsatisfactory because of the tenacious retention of solvent which, besides softening the film, renders the attainment of constant weight conditions impossible. The trichlorethylene extract values are excellent; the Freon-12 values of the thin coat are, however, too high.

The behavior of the polyamide-combination enamel in the cold toluene-methanol extraction test is good in the case of the thin coat, the heavy coat being sensitive to alcohol. Hot methanol softens up the enamel completely. Trichlorethylene extract figures are good, while the Freon-12 figures tend towards those for the DD; i.e., the extract values for the thin coat are too high.

Polyvinyl formal combinations show a very high loss of substance in the toluene extraction but are unaffected by cold methanol. Hot methanol, on the other hand, leads to a rather appreciable extract of 3.3%. The trichlorethylene extract at 4.33% is large, too. The Freon extraction of 0% is good and comparable with terephthalate.

A critical assessment of the situation shows that—while individual enamels show remarkable resistance to individual solvents—only terephthalate presents a balanced, often excellent—but always usable—level of resistance to all the solvents.

Normally, the suitability of enamelled wire for refrigerator units is evaluated by means of accelerated tests. There is a large number of such tests, in addition to those described. The accelerated tests are usually supplemented with functional tests in which the unknown insulating wire-enamel is submitted to a long-term test under service-like conditions. Periods of 6 to 12 months are not uncommon.

As chemists and manufacturers of enamels, we are, in addition, interested in any measurable change in properties which the extracted wire may have undergone. Comparative tests, such as the methanol-toluene or the hot methanol test, are not suitable for this purpose, since they are not related to service conditions. Considerable interest does, however, attach to the changes which occur during or after the treatment with trichlorethylene or Freon-12. To assess the effect of such treatment, we have—in another article—made use of the results of measurements of tan δ at various temperatures.*

*Schmidt, K., "The Solvent Resistance of Enamelled Wire," *Electrical Insulation*, no. 9, pp. 48-61, Dr. Beck & Co. (England), London (1959).

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Insulation in Canada

By V. R. Mulhall and L. P. Mahon, Engineering Laboratory, Canadian General Electric Co. Ltd., Peterborough, Ontario, Canada.

Canada is a land in which 60% of the population, concentrated in 1% of the land mass, produces 80% of the total secondary manufacturing. The total population is too small to support "American-sized" plants, or even to support heavy industry on both East and West Coasts, yet it is too thinly scattered across the continent for economical long haul transportation.

In this environment, the population and industrial centers have placed heavy reliance on the availability of cheap and abundant electrical energy. Canada's central station industry has approximately doubled its output of electrical energy every 12 years since 1900. In comparative world figures, Canada stands fourth in total production, being exceeded only by the United States, the USSR, and the United Kingdom. On the other hand, Canada's total annual power generation, on a per capita basis, amounts to 6000 kwh, compared with 45 kwh in the U.S. By this measure, Canada ranks second in the world, being exceeded only by Norway.

Now, as the last immediately available water power sites are being fully exploited, more attention must be directed toward long distance transmission from more remote sites, and toward coal-fired and atomic-fueled thermal generation.

These circumstances have dictated that technological development in the electrical industry in Canada be directed along specific and often novel paths. The major Canadian electrical manufacturers have become world renowned in the efficient design and manufacture of hydraulic generators, and have long been disciples of high voltage transmission. Intense development is in progress on atomic-fueled thermal generating stations, the first of which is expected to be in operation in 1961. The design and manufacture of fossil-fueled thermal generators in Canada is now in progress.

Canadian electrical manufacturers frequently find themselves in an awkward position relative to their United States counterparts. Much of this stems from their geographic and economic proximity to the United States. It is further complicated, however, by a government import tariff policy which offers little protection to the electrical industry. Thus, this industry now frequently finds itself in a squeeze play between American technical innovation and low cost European conventional equipment.

Technical innovation, originating in the United States, presents a challenge to Canadian manufacturers to offer similar developments to their customers. An example of this is the current emphasis on sealed insulation systems for motors. Perhaps it is more correct to say that the alert Canadian customer, kept informed by the periodical press, and also by personal contact with US manufacturers and users, *expects* such technical innovations. The Canadian manufacturer is thus forced to provide them or lose his position as a progressive supplier.

It is, however, not infrequently a great challenge to the Canadian manufacturer to incorporate such innovations into his product. The principal difficulty arises because of the comparatively small volume of business available to him in relation to that available to the US producer. High volume tooling, for example, may represent a substantial element of unit cost. Regularly, the Canadian manufacturer must utilize lower volume, lower cost facilities, and such substitutions are often ingenious. For instance, epoxy resins cast in low cost molds often replace pressure molded parts.

In addition, the smaller Canadian market regularly precludes the manufacturing of a full range of products necessary to cover a multitude of specialized applications. It is frequently necessary to employ judicious compromise and to make a few designs serve a maximum number of applications. This approach often calls for the development of distinctively Canadian insulation systems aimed at optimization and economy. The authors' company, for example, is successfully marketing in a wide range of sizes a motor having a dip-coated, epoxy-sealed insulation system; while our parent company, in three decentralized departments, employs three different systems. Each of their systems, however, serves a more specialized and restricted range of products peculiar to their respective product marketing areas.

The European electrical manufacturers have, within the last few years, emerged as a further complicating factor so far as the Canadian electrical manufacturer is concerned. In offering products of generally equivalent quality at prices sometimes as much as 30% below the prevailing Cana-

dian level, they have placed a tremendous pressure on Canadian producers to lower costs in order to maintain market position.

Such pressures naturally extend into the field of the insulation engineer where the careful choice and prudent application of insulating materials have enabled Canadian-designed products to meet the challenge of imports from lower cost areas, despite the absence of an adequate protective tariff barrier.

One measure of the results of these efforts is available in the 1959 statistics regarding hydroelectric generators installed in Canada. It is indicated in these that, to date, Canada has 19 million kw of installed capacity compared to 32 million kw in the United States, and of the Canadian figure, 93% of the generating equipment was designed and built in Canada. The giant St. Lawrence Seaway power project, which produces 2-million horsepower, has a total of 32 generators, of which 16 were designed and built in Canada.

Solid Insulation

The Canadian manufacturer utilizes essentially the same solid insulations as does his American counterpart. In fact, he frequently finds his sources for many of these materials in the United States. Notwithstanding this, there is in Canada a well-established insulating material manufacturing industry which competes with US suppliers.

At least five firms are engaged in magnet wire manufacturing and produce a complete range of products. Fiber glass and polyester yarns are manufactured, and from them the attendant tape and fabric products. Mica products are manufactured by at least two firms, and coated fabrics and plastic tapes are also produced. Finally, there is a well-established varnish industry supporting all of the above.

New developments in solid insulating materials represent another story. Here the Canadian electrical industry has been virtually totally dependent on the United States. The American supplier of such materials, or his Canadian agent, is always a welcome visitor.

Liquid Insulation

In Canada, as elsewhere, mineral oils for use in transformers and switchgear constitute the major portion of all electrical insulating liquids. In general, they conform with those used in the US, having viscosities of 56-60 Saybolt seconds at 100°F, as opposed to the more viscous oils used outside North America. In spite of the abundance of petroleum in Western Canada, domestic crudes are predominantly high in paraffins, and economically unsuitable for refining into low cold test oils. The Imperial Oil Co. does, however, import Venezuelan crude and produces transformer oil in sufficient volume to fill the majority of Canada's needs. Additional requirements are met by importation of fully-refined oil from both East and West Coast US refineries.

Canadian transformer oil is, in most respects, very similar to its US counterpart, but because of limited volume, it was deemed necessary to replace traditional acid refining by solvent and hydrogenation processes at a much earlier date than in the US. Today, Canadian solvent-refined transformer oil is a stable, well balanced, reliable engineering material.

For most applications in large power transformers and switchgear, uninhibited oil is used, but, following the general trend, many manufacturers fill specialty and distribution transformers with inhibited oil containing 0.3% by weight ditertiary butyl para cresol.

In the manufacture of oil-filled capacitors and cables, some European-type petroleum oils with aromatic additives have been used; but, in general, moderately refined oils without additives are the most common impregnants.

Askarels, the chlorinated aromatic liquids, are in common use in Canada, and their applications are almost identical with those in the US. These high dielectric constant, non-flammable, chemically stable liquids have filled a special need in transformers and capacitors for many years. Unlike the petroleum liquids, the total requirement for the Canadian market is imported from the US.

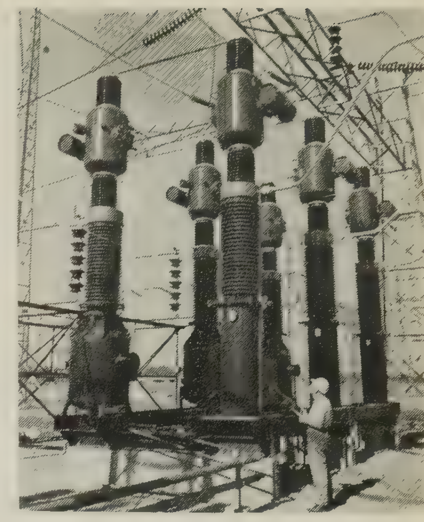


Figure 1, gas-insulated G-E type AT air blast breaker rated 20,000,000 kva at 230 kv in service at Burlington Station of the Hydro Electric Power Commission of Ontario. This breaker has the highest interrupting capacity at this voltage of any air blast breaker in the world. Gas pressure used is 40 psig.

Gaseous Insulation

In recent years, gaseous dielectrics have been given increased attention in specific applications. Since 1956, the authors' company has designed and built a range of high voltage instrument transformers for outdoor service at voltages up to 345 kv which are insulated with sulphur hexafluoride gas. Similarly, Canadian-designed air blast breakers, relying on SF_6 as their major insulation in high voltage bushings and associated current transformers, have been produced by the same manufacturer. These include breakers protecting the highest voltage rated system on the continent, the 360 kv system of British Columbia Electric, and the first 20,000,000 kva interrupting capacity 230 kv breaker, recently installed on the HEPC of Ontario system. This latter breaker has the highest interrupting capacity of any air blast breaker in the world in this voltage class.

More recently, during July and August 1960, three of the highest voltage outdoor, gas filled capacitors ever built anywhere in the world were shipped from CG-E's Davenport Works in Toronto to G-E's proj-

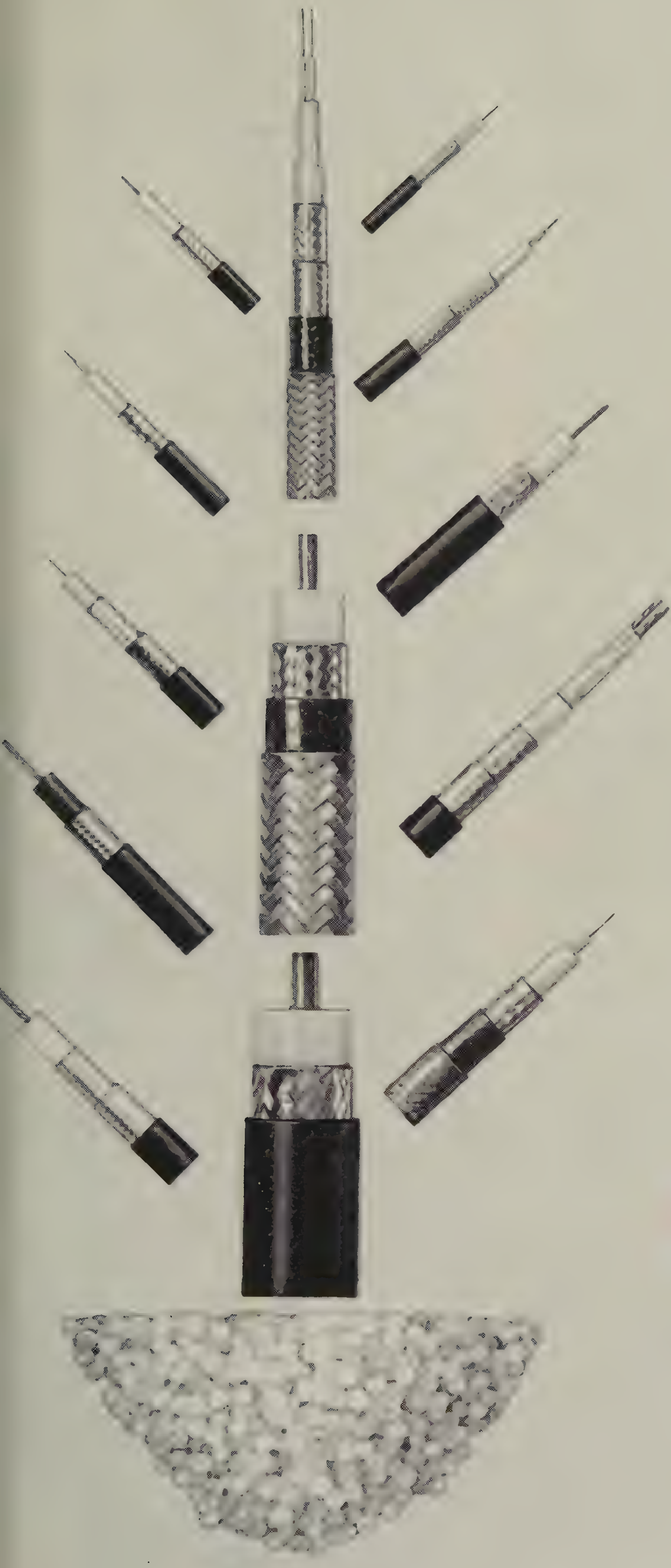
ect EHV in Pittsfield, Mass. These capacitors, insulated with sulphur hexafluoride, are capable of operation at voltages up to 750 kv.

These examples have been cited because the total volume of sulphur hexafluoride used in all this Canadian apparatus, to date, probably constitutes one of the largest electrical applications of this gas in the world.

Despite the differences outlined, it must not be concluded that the problems facing the Canadian insulation engineer are inherently different from those facing his counterpart in the United States, for we are all citizens of the same North American continent. The Canadian scientist or engineer, in fact, likes to feel that he enjoys a partnership with his American colleague in the solution of common problems. Thus it is that Canadians actively participate in the deliberations and decisions of the various technical and professional bodies, such as ASTM and AIEE. ASTM test standards are almost universally utilized in Canada, as well as are those of NEMA, through the corresponding Canadian Electrical Manufacturer's Association.

In the research and development field there is an ever-increasing amount of activity. This work is centered in such government and academic bodies as the National Research Council and Carleton University in Ottawa, and the Ontario Research Foundation in Toronto. In addition, the laboratories of the larger utilities and electrical manufacturers, such as the Hydro Electric Power Commission of Ontario, Canadian General Electric, and Canadian Westinghouse, carry out extensive research and development projects to fulfill the specialized needs of the Canadian industry.

In summary then, it may be concluded that, in the field of electrical insulation, Canadians are faced with essentially the same difficulties and challenges as their American colleagues, plus a few more that are distinctively Canadian. In the former, we enjoy the opportunity of joining our American friends in seeking solutions. In the latter, we enjoy the thrill of pioneering.



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Choice of Insulating Materials when Rewinding Motors and Generators

By Erik Hox, Director, A/S Rich. Pfeiffer, Sarpsborg, Norway.

When rewinding electrical machines, there will very often arise the questions of not only renewing the winding, but of completely redimensioning the winding, choice of another type of winding, another subdivision of the conductors, and—first of all—other kinds of insulating materials and methods.

Electrical machines are now subjected to harder service than they have been previously, and the demands on the reliability of the machines are greater than ever. The winding is often the weak point, and it is therefore important to make this as correct as possible for the conditions under which the machine will have to work. The quality of a winding depends on choice of insulating materials, type of winding, design of insulation, and good craftsmanship.

New insulating materials have come into the market, and new ones are continually coming; this applies especially to varnishes and bonding substances, and new combinations of insulating materials are constantly being developed.

Demands on Insulating Materials

The insulating material should have great mechanical strength, high dielectric strength, small dielectric losses, and good thermal conductivity; further, it should be resistant to heat, moisture, and corona. In addition, different properties are required varying with the use for which the material is intended. Some of these properties are elasticity, shrinklessness, dimensional stability, and resistance to leakage currents.

The arch enemies of all electrical insulation are high temperature, moisture, and corona.

Thermal Stability

Electrical insulation materials are divided into classes which specify fixed thermal limits for the different materials. These thermal limits according to IEC, AIEE, and Norwegian standards are shown in table 1.

Table 1—Insulating Material Classes

Insulation Class	— Max. Temp. in °C — IEC and Norwegian Standards	AIEE
A	105	105
E	120	
B	130	130
F	155	155
H	180	180
C	above 180	above 220

Class A insulation consists of materials or combinations of materials such as cotton, silk, and paper, impregnated.

Class B insulation consists of materials or combinations of materials such as mica, glass fiber, asbestos, etc., with suitable bonding substances.

Class H insulation consists of materials such as silicone elastomer and combinations of materials such as mica, glass fiber, asbestos, etc., with suitable bonding substances such as appropriate silicone resins.

In each class a proportion of materials of a lower temperature class may be included for structural purposes only.

The temperatures stated indicate limits that should not be exceeded. With a continuous load at these temperatures the insulation life is 5-10 years.

With insulation life we usually think of the time passed before the properties of the material have dropped below a certain minimum at which point vibration and other mechanical stresses would destroy the insulating properties. The dielectric properties, for instance the dielectric strength, can often be just as good, even better than before, because the material has been completely dried out. Insulation life diagrams are shown in figure 1. Usually one reckons that each 8 to 10°C temperature rise will halve the insulation life.

Ability to Withstand Moisture

When an insulating material absorbs moisture, the dielectric strength will fall considerably, and in this condition the material is quite unsuitable for insulating purposes, especially for high voltages.

Most of the insulating materials absorb moisture to some degree.

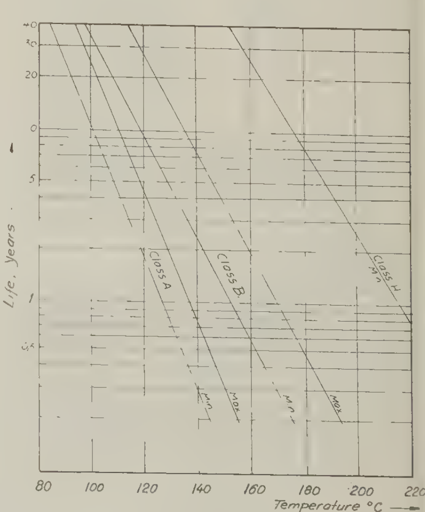


Figure 1, insulation life as a function of operating temperature.

Therefore, one will have to impregnate them, but even with a good impregnation one seldom completely avoids absorption of moisture. Oven-dried impregnating varnishes are the best ones in this respect, but then one must choose insulating materials that will stand the heat treating. As an example of how much moisture insulating materials contain, it can be mentioned that pressboard on delivery contains about 6 to 8% moisture.

It ought to be mentioned that surface moisture is very disadvantageous because it encourages surface creepage, and as a result of that, dielectric breakdown. The surface moisture can be very great under unfavorable thermal and weather conditions, especially after an interruption of service.

Corona Resistance

Corona usually is defined as a form of electrical discharge taking place when the critical voltage between two conductors is exceeded in a gas, such as air.

High temperatures in motor or generator windings can start corona in cavities in the insulation. One tries to avoid this by application of suitable compounds and impregnating varnishes; for instance, corona can start in the slots between iron and coil insulation. This can be avoided by application of a conducting varnish on the outside of the insulation. It can also start where the coil insulation protrudes from the slot and in coil end leads where there are field concentrations.

Corona is not dangerous in itself, but ozone and small quantities of nitric oxide are produced by the dielectric breakdown in the air. If there is moisture in the air, nitric acid will be produced which will attack the insulating materials and the conductors. High temperature will accelerate this process.

Critical signs of this development are that the copper assumes a bluish-green color, that some insulating materials are decomposed, that nitride and nitrate combinations can be found, and that the effects are different between the terminals and the neutral point according to the potential above ground.

One therefore ought to demand that the insulating materials are corona-resistant. Such materials usually are inorganic. Bituminous varnishes are also advantageous as they have proved quite resistant against nitric acid.

Corona seldom is a problem at machine voltages below 6000 volts. The thickness of the slot insulation, however, is important, as one is more likely to get corona with thinner insulation.

Likewise, the humidity of the air and the thermal conditions are of importance. We have seen 5 kv windings (voltage against ground 3 kv) which have been damaged owing to corona. For instance, if ammonia connections get access to windings the risk of dielectric breakdown by corona can be considerably greater than normal.

Insulating Materials

We are going to discuss some important insulating materials considering the demands mentioned above, namely thermal endurance, moisture resistance, and corona resistance.

Insulating materials such as paper, cotton, and similar materials, either impregnated or unimpregnated, are neither very heat-resistant, moisture-resistant, nor corona-resistant. Oil cloth is quite moisture-resistant and has good dielectric properties, but in other respects it is like paper and cotton.

Mica, glass fiber, and asbestos, when impregnated with a suitable varnish, comply with the demands for resistance to heat, moisture, and corona. These materials are inorganic.

Today mica, glass fiber, and asbestos with varnishes and bonding substances of epoxy, polyester, and silicone seem to be the usual insulating materials for high voltage motors and generators with class B insulation.

Mica was one of the first materials to be used as an insulating material and it seems to maintain its position. Today mica is used as splittings and also as small mica plates in mica paper. Mica splittings are placed on a backing of thin paper, fiber glass cloth, and thus we get different mica products depending on the kind of bonding substance and impregnating varnish. The materials may be had either in sheet or tape forms.

Micafolio is usually made in rolls of large width and with thin paper as backing. The binding agent used is a shellac or asphalt compound. The material is used as slot insulation and is usually applied by the Haefely method.

An essential weakness with this insulation is that it will swell during service (also during storage), and it does not seem to satisfy the increasing demands on insulation for high voltage motors and generators.

Bonding substances of epoxy and polyester materials may also be used, but then the application of the material is more difficult. A weak point in the use of micafolio as slot insulation is the joint between the slot insulation and the coil end insulation.

The use of tape instead of sheet allows the insulation to be made continuous; i. e., there will be no joints between the slot insulation and coil end insulation. Mica tape consisting of mica splittings on paper with asphalt compound as bonding substance is used as insulation in generators, and a careful workmanship gives good windings.

After the insulation is applied, the coils are vacuum impregnated with asphalt compound. However, in order to get a thorough impregnation the application of insulating material and vacuum impregnating must be done in several steps, depending on the total thickness of the insulation.

One advantage with this insulation is its elasticity, which is of great importance for the mounting of the coils in the machine. But this insulation also swells to some degree in the air gaps and outside the stator iron, and it is also subject to tape separation.

Mica tape consisting of mica splittings on a backing of thin fiber glass cloth with a bonding substance of epoxy or polyester contains no class A materials. This insulation is applied in full thickness, after which the coils are vacuum impregnated with thermosetting varnishes of epoxy or polyester. Then the insulation is pressed to exact dimensions, and the impregnating varnish sets at high temperature while the coils are un-

der pressure.

This insulation is heat resistant (class B), moisture resistant, and corona resistant, but it is not as elastic as asphalt mica tape insulation. On the other hand, the insulation will not swell, neither during service nor during storage, and it is practically not subject to tape separation.

Mica paper is manufactured much like cellulose paper, but the wood fibers are replaced by mica platelets. Epoxy varnish is commonly used as the bonding substance. The material is more homogeneous, more even, and more pliable than corresponding material of splittings. It is made both as sheet and as tape (so called wet tape) where the bonding substance is only partly cured.

A special type of mica paper tape is manufactured dry, and this is especially fit for the manufacture of high voltage windings with continuous insulation with subsequent impregnating under vacuum and curing under pressure. The method of application is the same as for mica tape of splittings. Glass fiber is used as backing also for this type of material. The quality of this mica paper insulation is at least just as good as that of mica tape made of splittings.

Which of the two materials, tape of mica splittings or of mica paper, should be preferred as insulation for high voltage motors or generators is difficult to say at present.

In our opinion, it is rather certain that both insulating materials will be used more and more, and that they will increase the dependability of electrical machines substantially.

A very important point in the use of these materials is that the vacuum impregnating must be done very carefully and that a vacuum of 50—100 microns ought to be used.

Partly cured mica paper tape (wet tape) can be used as insulation for low voltage windings without a vacuum treatment. During the curing process the bonding substance will become fluid and one will get a homogeneous insulation. If this wet tape is used for high voltage windings, the insulated coils must be vacuum treated before the insulation is cured.

Fiber glass is produced in the form of very thin fibers of suitable glass. From these fibers one produces, for instance, glass tape (which replaces cotton tape), and varnished glass cloth and tape (which are used instead of oil cloth and oil tape).

Varnished glass tape has the same good dielectric strength as oil cloth tape, but the glass permits the application of oven-curing thermosetting varnishes; that is, varnishes satisfying the demands for class B temperature operation.

Silicone varnish is also used as impregnating varnish for glass cloth and glass tape. It can provide a product fully satisfying the demands for class H heat resistance, moisture-resistance, and corona-resistance. Silicone varnish is water-repellant.

Impregnated glass tape is used as insulation for single conductors and windings, especially for low voltage machines and as coil end insulation for high voltage machines.

Asbestos and fiber glass cloth impregnated with bonding substances of epoxy or polyester in semi-cured condition are excellent as lining between parallel strands of conductors, for instance, between windings in field coils. When cured under pressure the conductors will be bonded together making a compact whole.

Silicone rubber tape may be had either reinforced with glass cloth or not reinforced. It is the latter type that is preferred as insulation for high voltage machines. After the coils are insulated they are cured under pressure at a high temperature.

The insulation is flexible and satisfies most of the demands one can make upon a high voltage insulation. It allows a temperature of 180°C, but for usual motors and generators it is hardly appropriate to make full use of this limit. We think that class B ought to be sufficient.

As insulation of silicone rubber will be more expensive in Norway than, for example, insulation of mica paper, we think that silicone rubber first and foremost ought to be used for electrical machines working under extreme conditions and in a very unfavorable atmosphere such as in chemical plants.

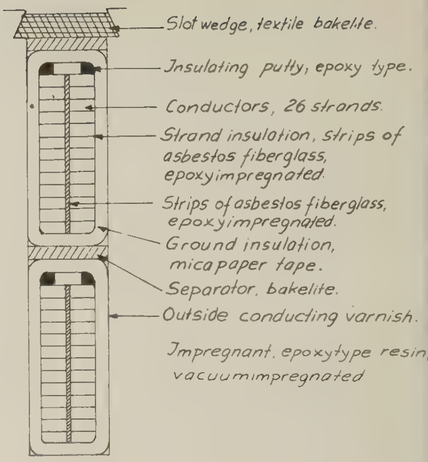


Figure 2, insulating arrangement for a Roebel bar.

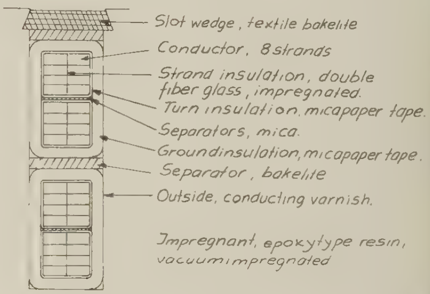


Figure 3, insulation arrangement in the slot for symmetrical coils.

However, prices and points of view are changing, and time will show for which conditions silicone rubber will be used in insulation engineering.

Choice of Winding and Insulation

We have mentioned that when choosing the type of winding one ought to take into consideration the type of insulation.

For larger machines it will be advantageous to use two conductors per slot in the form of two bars each with full insulation against ground. The conductors are subdivided in strands which are transposed in the slot, the well known "Roebel bar."

The bar may have continuous insulation and require very little elasticity. This is a mechanically strong winding which is easy to install and easy to repair.

The use of special hoops which are hard soldered to the ends of the bars will give strong connections between over-bars and under-bars. This will also facilitate the mounting of the winding. An example of an insulation arrangement for this kind of winding is shown in figure 2.

The coils for machines with sev-

eral conductors per slot are usually made as complete (not split) coils. They may be symmetrical windings with two coil sides per slot or concentric windings with one coil side per slot.

Usually these coils will have to be bent a little during the mounting in the slots, and it will therefore be necessary that the coil ends have a certain flexibility.

It may be inadvisable to use a continuous mica insulation with epoxy or polyester thermosetting varnishes for these kinds of windings.

The slot insulation is usually most exposed, and the demands upon the coil end insulation are far less severe. One may therefore use mica insulation for the slot insulation, and varnished fiber glass tape as coil end insulation. Between the slot insulation and the coil end insulation sloping joints can be made. The outer layer of the coil end insulation is made of untreated fiber glass tape, which is afterwards impregnated with a suitable varnish. An example of the arrangement of slot insulation for this kind of winding is shown in figure 3. The use of mica tape with asphalt compound has in this case the advantage that the coils will be slightly elastic.

Eddy Current Losses

In older motors and generators the stranding of the conductors is very often unsatisfactory and may cause great eddy current losses. Before rewinding a machine it is often necessary to check the eddy current losses and it will very often be found necessary to alter the design. Choice of another type of winding will then come into question.

It is the eddy current losses in the slot which are of greatest importance, and of these we have two kinds, namely:

a) Eddy current losses due to current displacement in the conductors resulting from the magnetic field created by the current in the conductors themselves (figure 4a). As the current is displaced upwards in the slot, the current displacement, and therefore the losses, are greatest in the top of the slot, where the field is strongest. In order to reduce the losses, one must sufficiently divide the conductors and insulate the single strands against each other, but one must make all the strands carry the same current; for example, by transposing them.

b) Eddy current losses owing to the penetration of the pole field into the slot (figure 4b). These losses practically never occur in closed or half-closed slots. These losses are also due to current displacement, and one reduces this by dividing the conduc-

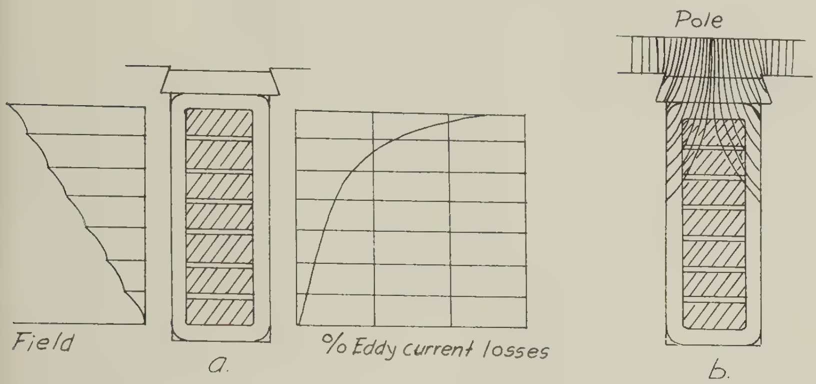


Figure 4, types of eddy current losses: a) current displacement due to magnetic field created by the current in the conductors, and b) losses due to penetration of the pole field into the slot.

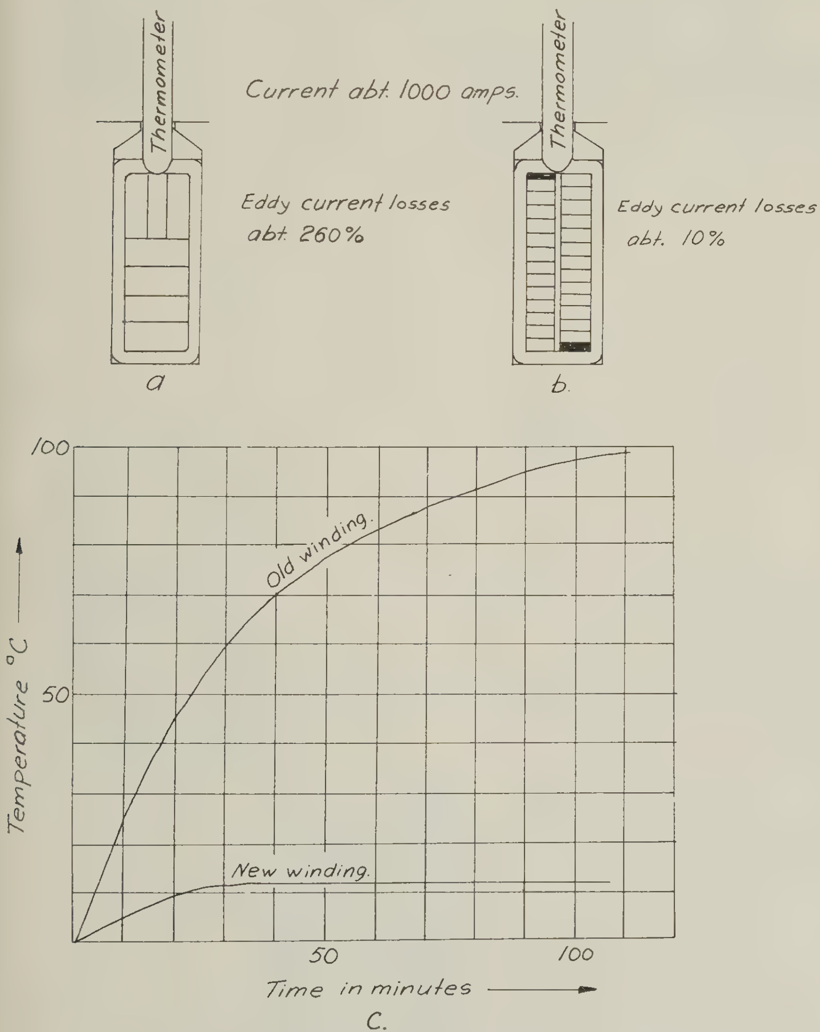


Figure 5, section of a large generator slot: a) old winding, b) new winding, and c) comparison of the two connected in series and by full-load current.

tors—usually it is sufficient to divide the topmost conductors—and by not placing the connectors too near the opening of the slot. In wide slots and wide conductors, especially with high induction, the losses can be quite great, and can result in great local heating.

c) Example of faulty design. Figure 5a shows a section of the slot of a large generator. The stranding of the conductors was quite horrible. The topmost conductors were divided in the width, but the slots were only half closed. All strands were higher than the "critical conductor height." The strands were not transposed; transposition would in this case have resulted in even higher losses.

The strands were insulated against each other, but this only made things worse, because the insulation partly hampered the equalization of temperature in the slot. A solid conductor would have given smaller losses and lower temperature.

In figure 5, b shows a section of the bar-winding of the Roebel-type used to rewind this generator, and c shows the result of a test made with a new and an old coil connected in series at full-load current. The temperature was measured directly on the copper as indicated in a and b.

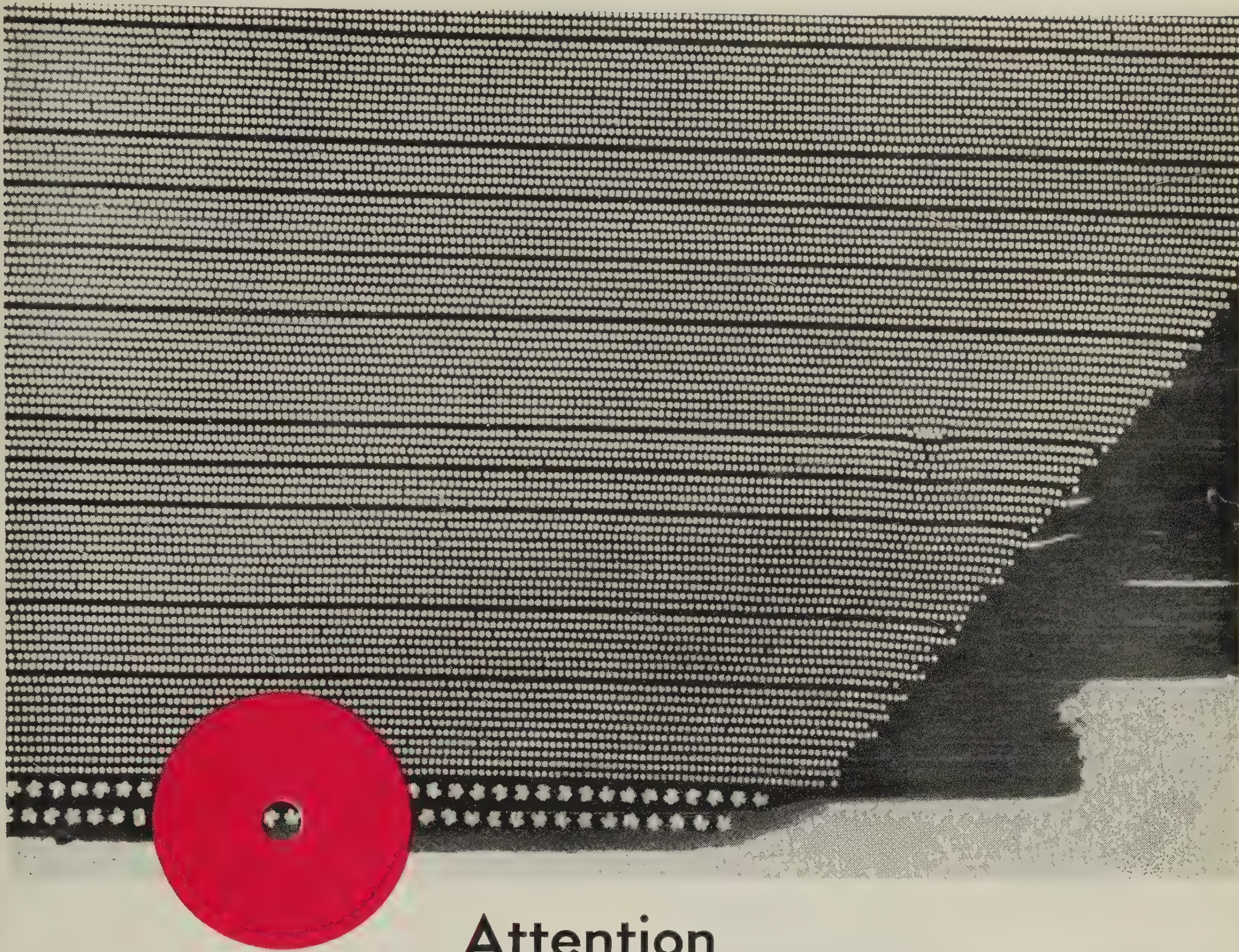
It must be supposed that maximum copper temperature for the old winding had been about 150°C. It lasted 15 to 20 years before any faults occurred, but then the slot insulation. consisting of shellac-mica sheet, had partly disappeared.

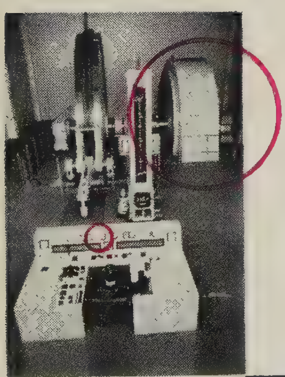
Summary

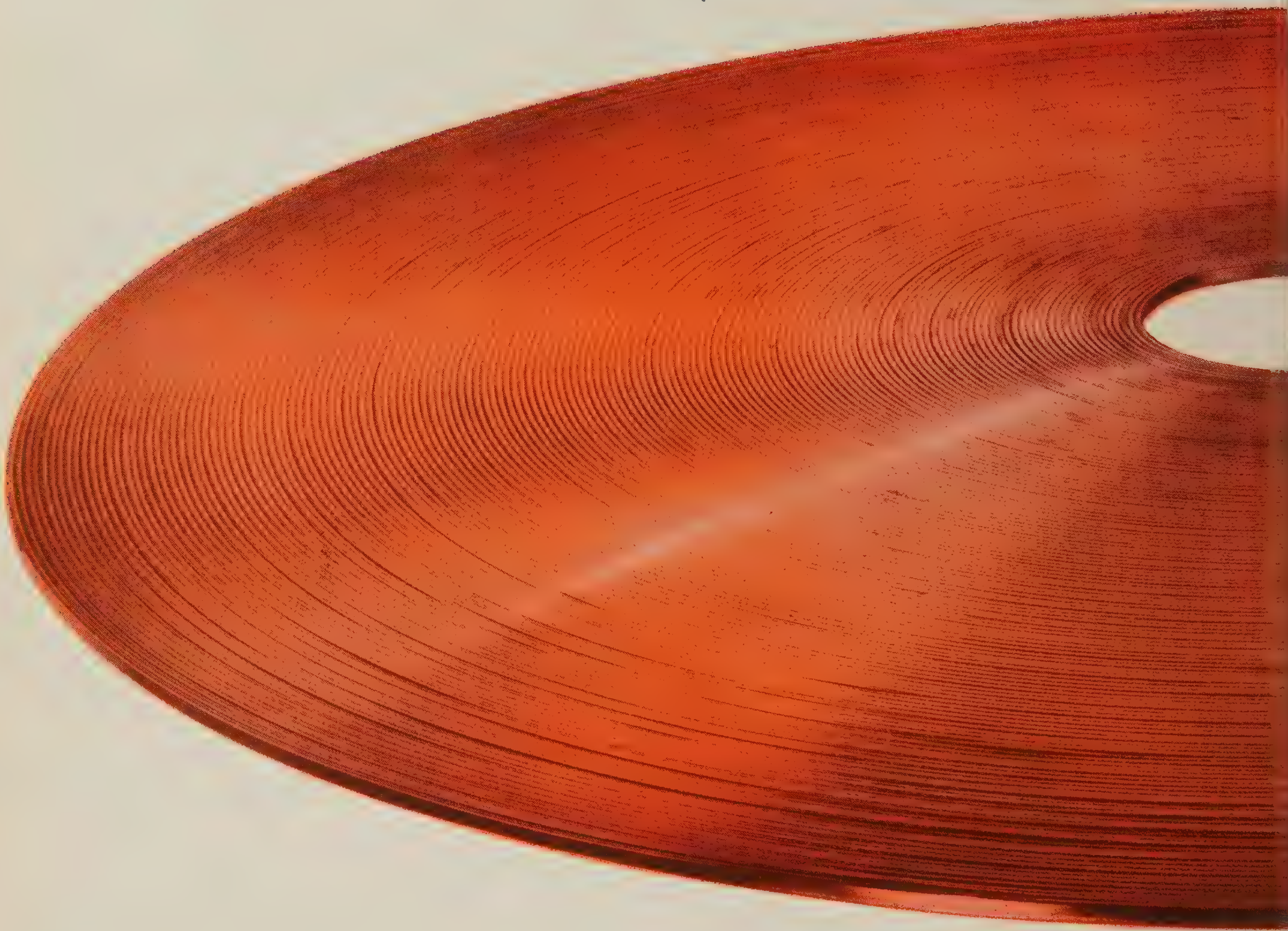
The most important demands to be made upon insulating materials for motors and generators, especially for high voltage machines, are stated.

On this basis we see that the following materials stand out as meeting the demands of class B: Mica, fiber glass, and asbestos with bonding substances of epoxy and polyester.

Silicone rubber meets class B demands and also those of class H. Finally, some examples of usual types of windings and insulation arrangements are given, and some remarks are made on eddy current losses in copper conductors.







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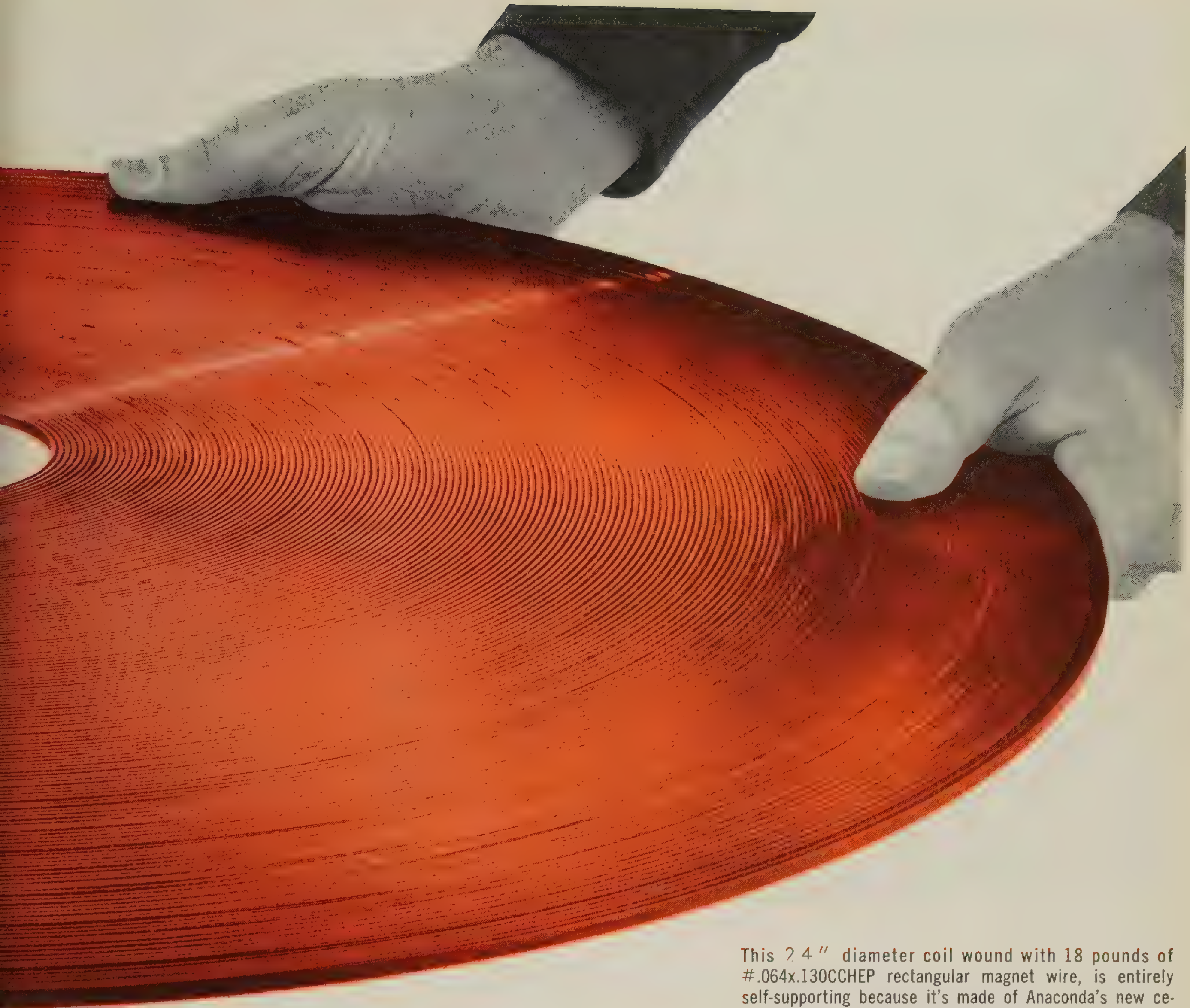
And here are some other advantages: Anaconda cement-coated epoxy magnet wire won't hydrolize in closed systems because the cement is an epoxy type



This 24″ diameter coil wound with 18 pounds of #.064x.130CCHEP rectangular magnet wire, is entirely self-supporting because it's made of Anaconda's new cement-coated epoxy magnet wire. The outstanding bond-strength of this wire is stable at high temperatures, too. Coils can be removed from oven and handled while still hot without danger of deforming—as shown in picture below.

that hold their shape without support ...both cold and hot...even at 200 C

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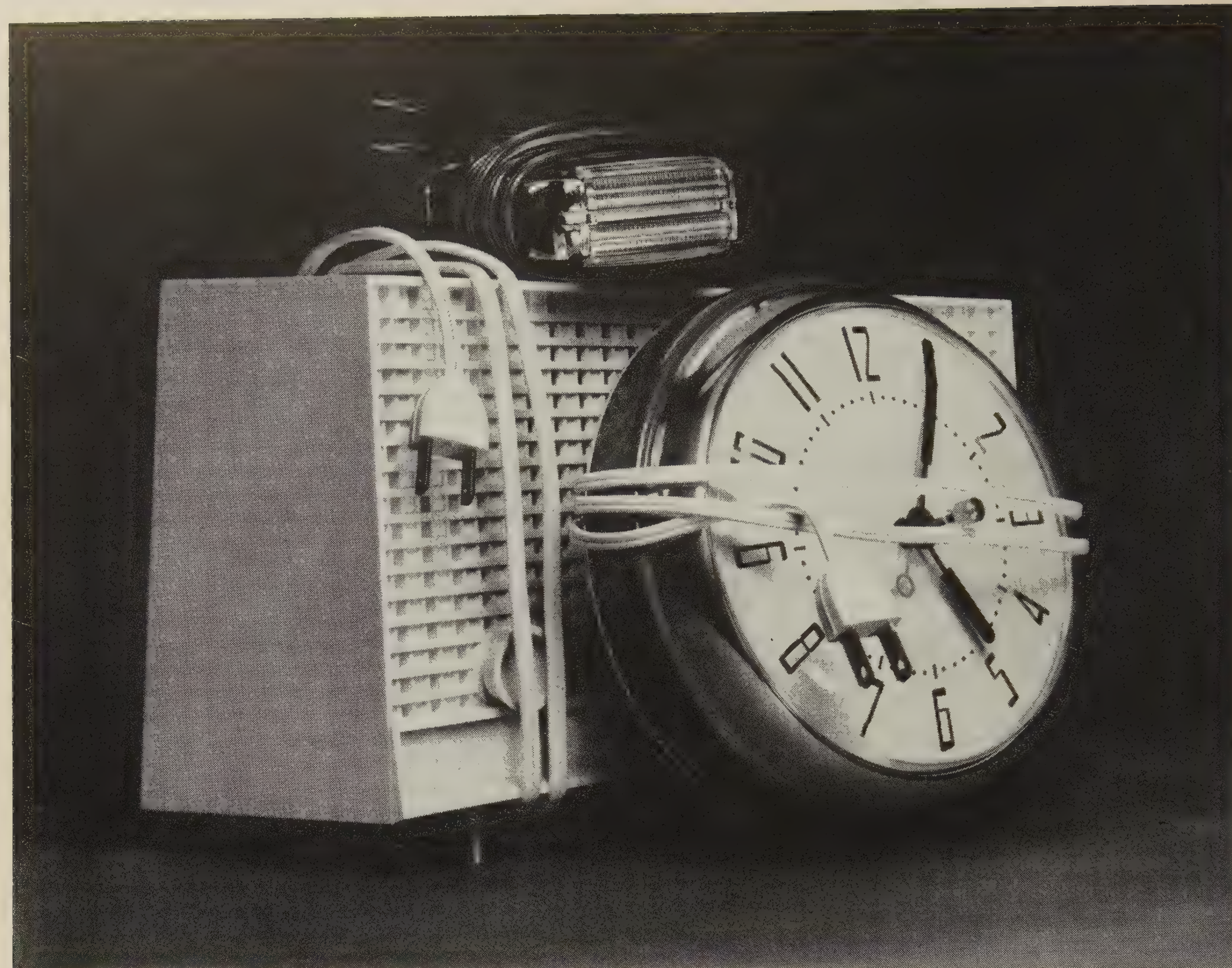

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Insulation Materials and Techniques for High Frequency Welding of PVC Film

By Vivian Bird, Pinner, Middlesex, England.

The simplest method of bonding two pvc films by means of high frequency welding involves the use of a simple bridge electrode without cutting edge and with fixed limit of travel. HF film welding by means of a bare bridge electrode was exclusively employed when this technique was first introduced and is still used today in certain cases. The use of cutting edges on the electrodes coupled with the wide range of film types available have resulted in even greater importance being attached to the associated welding auxiliaries. The function of these auxiliaries is to facilitate the welding operation and to reduce wastage in production by eliminating accidental perforation, etc., of the work.

The most commonly used insulation material in the welding of pvc film is hard-paper (generally known as "Pertinax"). This material consists of phenol resin and cellulose paper and has without doubt certain advantages. It is reasonable in price, remains level a long time, and gives the welding material a gloss on the underside. Hard paper is used in thicknesses of 0.1, 0.2, 0.3, 0.4, and 0.5 mm. Although it possesses advantages from a technical welding viewpoint, 0.1 mm hard-paper film is not very popular since waves or undulations frequently form in it after short use and render the materials unusuable.

The insulation material most closely related to hard-paper is paper itself. It is used in the form of oil paper or similar material ("Pergamin"-paper) in cases where a symmetrical HF weld is required. At the same time, Pergamin-paper is also the cheapest insulating material. Occasionally Pergamin-paper is also applied as an additional insulating layer on Pertinax. Recently there have appeared on the market synthetic-layered papers, which undoubtedly in certain cases can be advantageously used as insulating materials.

Rubber-cloth is used far more frequently than paper. It has the advantage, among others, of equilibrating small inaccuracies in the electrode and of effecting a soft passage (or blending) in the use of unequal material layers. There are various types of rubber—for example, cheap bed-rubber. Although this type of rubber is frequently used, it is not recommended. The rubber becomes unusable after a short time owing to the formation of undulations. It also possesses poor qualities with regard to its equilibrating effect and spark-over resistance. Considerably better, on the other hand (also more expensive), are natural-rubber plates. Admittedly, with this quality of rubber, undulations still cannot be completely avoided. However, the elastic and HF technical characteristics are much more favorable. A variation of the rubber-cloth is rubber-fabric cloth. Here again there are cheap types available with one-sided fabric layering. The best quality of this type is rubber-cloth with double-sided fine silk cambric fabric layering. This type possesses the desirable qualities of the natural-rubber cloth and is almost completely free from warping. The sole disadvantage of rubber and rubber-fabric cloth is that the former provides a weak welding-seam underside, while the later leaves the fabric-structure behind on the same. In addition, templates can only occasionally be manufactured from this material.

As a final rubber type, mention should be made of rubber-graphite. This is used up to 5 mm and does not serve as insulation, but rather as a conductor of current—it causes an increase in the dielectric loss angle. From an HF technical aspect, it has the effect of resistance, thereby representing additional heat losses. It is used almost exclusively in the welding of pvc with materials or with "Moltopren" and up to the present time has attained no great importance in this field.

An insulation material commonly used in recent times is a bonding of a glass fabric with silicone. This material is chiefly used in thicknesses of 0.2 and 0.3 mm. It not only possesses particularly favorable electrical qualities, but also high perforation resistance. A further characteristic of this material is that the film does not stick after welding to the insulation material which facilitates removal. The fastening of the material to the underplate must be by mechanical means.

Finally, there are still other aids such as "Teflon," Teflon-glass fabrics, linen fabrics (partly impregnated

with oil), and lacquers. The latter however, will not be discussed here owing to high material prices and low wear-and-tear-strength. At the same time these materials should not be completely rejected since it is quite possible that one of them possesses special qualities for certain welding applications. All the previously mentioned insulation materials relate essentially to pvc film for which the insulating medium is mostly inserted between the under-plate and the welding material.

In addition, two other methods are employed. The first involves placing of a rubber-cloth between electrode and welding-material. This system is used particularly with metallized films or thin transparent film. The use of rubber cloth prevents surface burns and contributes towards increased heating of the edge zones. By suitable design of the electrode the welded seam is not materially influenced (in given cases, the rubber cloth can still be greased). The rubber coating over the electrode is, in certain instances, also used where the edge is to be welded over to exact trimmings without the use of cutting edges, e.g. transparent dust-covers for books made of film approximately 0.1 mm thick with Moltopren welds.

The second procedure is used in welding involving a counter-electrode. In cases, where welding with bare electrodes is inadmissible, use is commonly made of rubber cloth, which can also be used in connection with a Pertinax, pasteboard, wood, or metal frame laying-in template. In particularly critical cases, the insulating material can also be used on both sides, whereby however, a weakening of the welding seam is unavoidable.

Technical welding auxiliaries become of increasing importance when very thin films have to be welded and when mixed polymers, polyamides, acetates, and similar materials are used. In these instances, it is frequently found that a single insulation layer is insufficient and accordingly a two-layered material must be used. It is also strongly recommended that in the welding of thin films, counter electrodes be used to ensure a symmetrical HF field.

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The Problem of Functional Tests With Solid High Voltage Insulation

By O. F. Wohlfahrt, Brown Boveri & Co., Ltd., Baden, Switzerland.

Soon after the second world war there appeared on the market whole groups of new insulating materials whose properties were such that a new definition of the thermal classes became necessary. The old system of classifying insulating materials into thermal classes based on their chemical compositions was replaced by a much looser and more general concept. The new standard classifies materials by means of functional tests. With these functional tests, the insulation material to be tested is stressed as far as possible in the same way as it would be stressed during service. In the final analysis, only the verification of the complete insulation system of an apparatus in actual service can decide whether the choice of materials made was correct. This was, of course, valid for the designer until now, even without a standard. But he must now show proof of the fulfilment of these requirements with the help of test results, whereas earlier a list of constituents within the proper thermal classifications was sufficient.

Naturally, when developing new insulation systems and introducing new materials, one cannot wait until service experience is gathered. The test time has to be shortened, and this can be accomplished by aggravating the stresses. In order to save unnecessary costs, the apparatus is simplified to a model, which consists only of the essential parts directly influencing the behavior of the system and its mounting. With electrical equipment where the insulation is mainly thermally stressed, the new principle proves itself very well. The additional stresses, such as voltage, vibration, humidity, etc., in test practice actually effect only a sharper and clearer selection or differentiation, i.e., making apparent the aging resulting from the thermal stress. The criterion for success or failure as a measure for the continued serviceability of the insulation system is in almost all cases the failure of the system with voltage tests.

This new technique of classifying materials is, without doubt, much more complicated than the very clear and distinct old classification based on chemical composition. In one case, a particular material could conform to, say, class F but not in another.

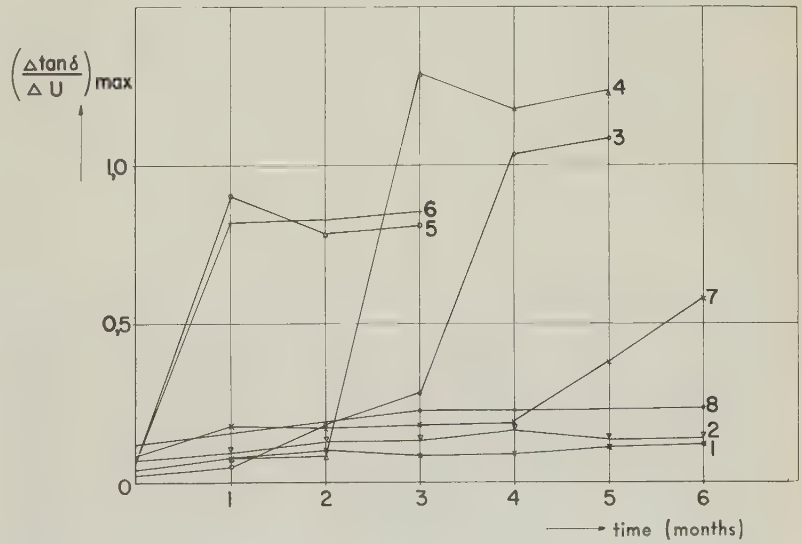

Figure 1, maximum rise in tan δ (%/kv) as a function of aging time (months). Curve 1, 3, 5, 7: aging with 135°C and 18 kv (corresponds to approx. 3 times the service voltage determined on the basis of the insulation thickness of the sample). Curve 2, 4, 6, 8: aging with 135°C only. Curve 1, 2: Micadur insulation (glass cloth, special synthetic resin, mica paper). Curve 3, 4: paper, mica paper and Micadur synthetic resin. Curve 5, 6: paper, asphalt, and mica splittings. Curve 7, 8: glass cloth, polyester, and mica paper.

With simple equipment (low-voltage motors, dry-type transformers) such tests can be performed successfully within a reasonable length of time without undue expenditure.

As an example, figure 1 shows the behavior of different insulation materials in an aging test at 135° C. Copper bars were insulated with the insulation. The insulated bars lay freely in the aging oven; that is, they were not held in any slot model. The Δ tan δ / Δ kv values on the ordinate are simply a measure for the alteration of insulation quality as a function of the aging time. How this value rises and what it signifies is shown in appendix II. It can be clearly seen that material combinations, which themselves belong in the same thermal class, behave very differently with respect to the measured values.

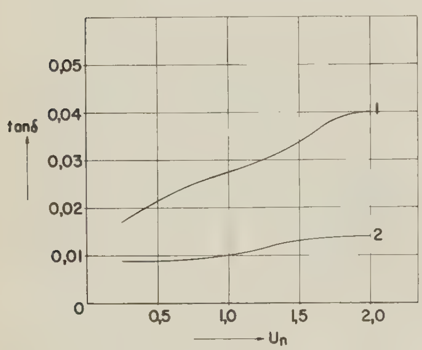

Figure 2, influence of curing temperature on the dielectric properties of a synthetic resin insulation. Power factor (tan δ) as a function of the voltage U measured on an insulation at 20°C. Curve 1: cured at 140°C. Curve 2: cured at 110°C. U_N = rated voltage.

The picture changes, however, when the important stress occurring continuously in service is not only thermal but also electrical, as is usual with high-voltage equipment. The dangerous stress which very quickly causes significant aging of the insulation is not the potential as such, but the fact that there are electrical discharges both inside and on the surface of the insulation, the form of which may vary from a glow to actual arcing discharges. This is especially important when the ability of the insulation material to withstand corona determines what corona intensity is permissible. The classic example is the stator winding of high voltage rotating machines. Here, only that sort of corona which endangers the life of the machine is undesirable—those factors usual with transmission lines and other outdoor equipment (e.g. radio noise, corona losses) have no significance whatsoever.

Since the definition of the test is based only on the proof of thermal quality, it is not possible to distinguish whether the voltage or the heat is the main cause of failure. For example, too little is known to assert that the functional test shows that a system meets, say, class F. Even when corona might be the main cause for aging of a system, the result indicates the service temperature that the equipment can withstand, not which voltage.

With small low-voltage equipment, the determination of the materials which do not meet the requirements is mostly very simple, and an exchange for a similar but better material is possible without much complication. However, the compatibility of the individual materials is a very important factor in the case of high voltage insulation systems. An alteration in the system is usually accompanied by further changes.

When any enamelled wire or slot liner in a motorette test corresponding to the AIEE proposals suffices for a particular thermal class, then in practically all cases it will also suffice for the stator winding of a corresponding motor, since the constructions hardly differ in their essentials and the decisive stress is solely the hottest spot temperature. Accordingly, a list of materials recommended on the basis of such tests is possible. With high voltage insulation, however, the manufacturing process, among other things, also plays a decisive role. Bad impregnation, solvent separation, humidity during service, etc., result in voids in the insulation. The thermal durability of the material will be hardly influenced by this, even if the heat conductivity becomes a little worse. However, with materials sensitive to corona, the rate of aging will be significantly influenced by the discharges taking place in these voids.

Figure 2 shows an example of the difference in insulation quality when one of the many variable factors in manufacturing is changed.

Test Layout for Functional Tests with High-Voltage Systems

For small motors and dry type transformers, a type of standard was developed which now exists as a recommendation. All service conditions can be simulated in a single model test without great difficulty. The objects are small, simple models can be produced, and even original ones can be used for testing purposes. A large number of variants can be simultaneously tested without large expenditures.

In contrast, high-voltage equipments are mostly big. It is hardly possible to test with the original object. For example, let us consider

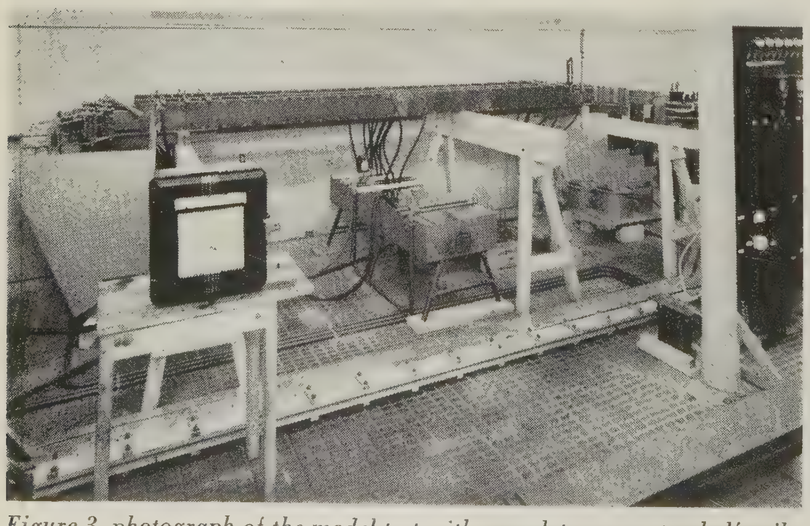

Figure 3, photograph of the model test with complete generator half-coils.

the insulation of the stator windings of a large generator, which is perhaps the most complicated case.

The factors which influence all the results and the conditions which must be maintained are:

a) The price of the insulation materials and the wages paid for insulation of the winding are an important part of machine costs and must therefore be kept low.
b) It must be possible to fit, and if necessary (e.g. due to failure during service), dismantle the half-coils individually without damaging them.
c) The insulation is thermally stressed.
d) The insulation is electrically stressed, but, due to technological and constructional reasons, corona is not completely avoidable. The insulation is also exposed to discharges and to possible corona products.
e) The expansions of copper, iron, and insulation as a function of temperature are very different, so that during a change in the generator load, large displacements and mechanical stresses occur in the winding.
f) The occurrence of humidity and dirt is unavoidable.
g) Special requirements of design must always be taken into consideration.

It is clear that the large number of elements of such an insulation system, from strand insulation to corona protection, must be tested under all stresses with respect to their behavior and mutual influence. This is impossible in a single test. Division of the test is necessary. In order to avoid many variants, extensive preliminary tests on individual materials with individual stresses are indispensable. These tests can then be kept very simple, since the more complicated and costly test with the selected material remains unavoidable. For example, 80% of the tested synthetic resins could be designated as inapplicable for use as impregnating resin for the insulations of stator windings (hottest spot 130°C), by means of a visual examination after aging the resins for a few days at 150°C. With the rest, complicated model tests were carried out until only a few resins with the best prospects for success were selected. This selection was then used for the concluding test. Figure 3 shows such a test. The copper conductor was heated with an electric current and the dummy slot was cooled with water in order to attain the particular temperature drop over the insulation. The heating current is switched on and off in a cycle of a few hours (cooling down to 20°C, heating up to 155°C at the copper, 80°C at the slot wall). The insulation is stressed with 1000 such heat-cool cycles. Apart from this, a voltage of 18 kv is applied to the copper, corresponding to about 1.5 times the service voltage. The end connections are stretched and the half-coils have the same tolerance in the model slot as could be expected in a machine.

For stresses which cannot be simulated in the model slot, the best course is to perform special tests in each case. The aged bars in the model slot are, for example, subjected to a mechanical test which corresponds to the mechanical stresses during assembling and dismantling of the bars and during short circuits (see figure 4). The insulation is stressed with voltage and temperature during the mechanical test.

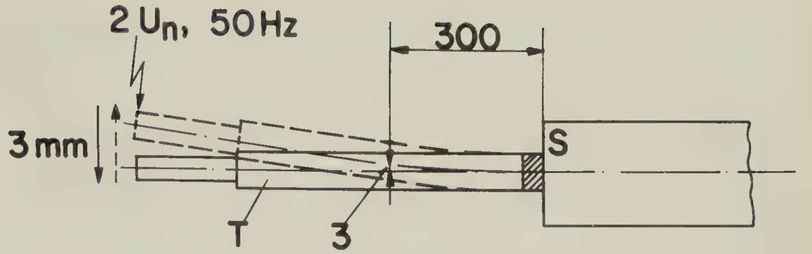

Figure 4, endurance tests with mechanical stress on the head part, temperature and voltage. T = test bar. S = model slot. The insulation is stressed with two times the rated voltage U_N and is bent until electrical breakdown occurs.

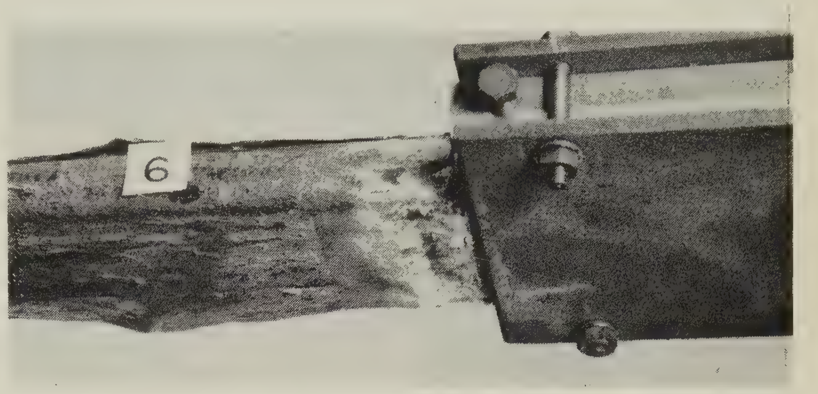

Figure 5, results of an endurance test with temperature and voltage. The test bar was pressed between plates in one part and in the other part was free. Corresponds to both the extreme cases of stretching a half-coil in the slot of a stator.

The smallest design change is often enough to evoke a different type of aging. For example, the results of a test with current and voltage are shown in figure 5. The thermoplastic resin proves excellent if the bar fits tightly in the slot, but if there is tolerance in the slot, it is very bad. For a rough demonstration, a part of the half-coil was pressed between plates and the other part lay free. In the non-pressed part, the insulation loosened itself from the copper and corona set in, thereby disintegrating the resin, and the gases generated caused the insulation to swell.

The test engineer should be able to estimate the stresses correctly and spread them between individual tests, although the main stresses must be present in every test. With high voltage systems it is seldom possible to have a test which reproduces all the

service conditions clearly and exactly.

Possibilities of Accelerating the Tests

The necessity to perform, one after another, the test for the first selection, the tests of the various components of the system, and the final concluding tests compels acceleration of the tests as much as possible.

An acceleration of the tests by increasing the temperature of the copper conductor is an obvious possibility, because the temperature is usually one of the main stresses and there is a law (see appendix I) which gives the relation between the aging temperature and life. It is best to choose an aging temperature one class higher than the hottest-spot temperature to be expected in service. Mechanical stresses should only be increased slightly above the actual figures, if at all.

The test conditions become difficult to survey when the voltage influence has to be considered. An increase in voltage can transform glowing discharges into arcing discharges so that the arcing points attain a temperature several times higher than the test temperature.

Another way of accelerating aging is by increasing the frequency of the applied voltage (e.g. 1200 c/s instead of 60 c/s), the rate of destruction by electron bombardment being increased but the chemical reactions, which might possibly have a much greater influence on the rate of aging, are hardly hastened by it. These are, however, strongly influenced by a change of temperature. Because of the chemical reactions the test should also be carried out periodically at room temperature in every case so that the corona products, such as ozone, various nitrogen oxides, etc., can combine with water to form acids.

The anticipated possibilities must always be weighed carefully on the basis of the results of fundamental tests. Figure 6 shows an example of the two principal cells for corona tests. With such test cells it could, for example, be determined that a particular silicone rubber was good or bad, depending on the cell in which the test was carried out. A semi-conducting layer was formed on the sample with direct electrodes which provided corona protection, so that all corona was suppressed. Thus, the sample proved itself to be resistive to corona. In the French cell, the rubber was attacked, especially by the nitrogen oxides, so that it lost all mechanical strength after a short time. The half of the sample which was not directly between the electrodes also lost its mechanical strength, having been attacked by the gases. The half of the sample which was between the electrodes crumbled to pieces completely under the electron bombardment because it did not have any mechanical strength left.

With all these considerations one must reflect on what has actually taken place and what else could happen. The choice of the correct magnitude of the stresses demands a lot of experience and should be reconsidered from case to case. Every insulation can naturally be tested to destruction in a short time. The test should, however, be such that conclusions with respect to actual service are possible.

Evaluation and Critical Examination of The Test Results as Well as Continuation of Aging

Philosophy says that the test should produce the proof that the insulation is in a position to fulfil its destined task in service. In order to produce this proof, a relation between test and reality has to exist in order that the results may be converted to reality. This conversion can be calculated by means of a known law (appendix I) for the tests with thermal stresses. It is naturally assumed that the criterion for the failure of the system or a part of the system actually gives the desired information on its serviceability.

The conversion of the results of other tests as they are represented in figures 7 or 8, or even in figures 3 and 4, can be accomplished only by a relative comparison. It can be stated that the corona protection paint A has proved successful in service and withstood friction x times whereas the paint B withstood friction significantly less than x times. It is impossible to estimate how much worse it will prove to be in service. It is only certain that B is worse than A and therefore there is a risk of its failing in service.

The test represented in figure 8 was used to select the most suitable insulating tube between the grounded part and the part under voltage of compressed air equipment. It was feared that the humid compressed air or, when kept outdoors, the weather conditions would favor creepage on the insulation. The tube became progressively weaker until the compressed air burst it open. The applied voltage which was double the service voltage and the aggravated external test conditions caused all the tested tubes, stressed for different lengths of time, to fail within six months. With respect to the expected service life, it could then be stated that the tube C was by far the best in the test and should also prove to be the best in service.

It is not advantageous with large-scale tests to adopt the usual practice of, say, applying a test voltage periodically in order to undertake a separation and to obtain a measure for the degree of aging. Too few samples can be tested within a reasonable time and at tolerable expense in order to

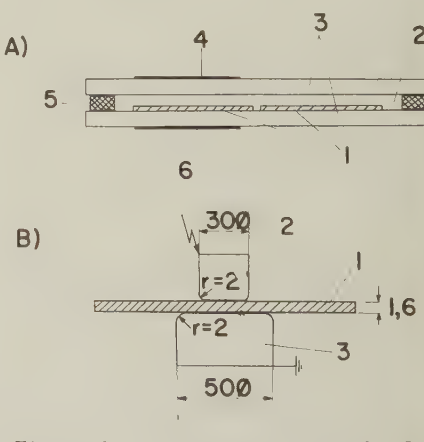

Figure 6, test arrangement for fundamental corona tests. A) French cell: 1—One sample between the electrodes and the other exposed only to the gaseous corona products. 2—Air gap (corona space). 3—Micaver plates 260 × 180 × 2 mm. 4—High voltage electrode (8 kv, 50 c/s). 5—Glass spacer (2 mm). 6—Ground electrode. B) Cell with direct electrodes (measures in mm): 1—Sample. 2—High voltage electrode (15 kv, 50 c/s). 3—Ground electrode.

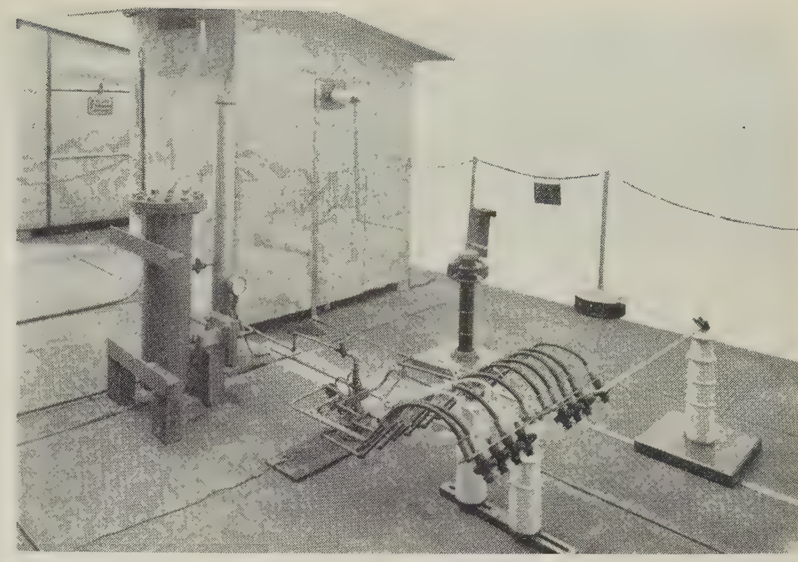

Figure 8, test arrangement for testing the serviceability of insulating tubes for a compressed air system.

obtain a sufficient number of breakdown values to evaluate them statistically. The results have a large dispersion because of the difficulty of reproducing the samples exactly and because of the many other non-controllable factors. It is not the average but the minimum value which has to be determined.

Tests on systems where service experience is available and on newly developed systems should therefore be carried out simultaneously in such cases. The tests should be checked periodically against non-destructive measurements in order to obtain a measure for the aging and any changes taking place. Such measurements regarding the behavior of the so-called comparison systems should also exist in order to obtain a time calibration of the accelerated test. Known non-destructive tests are as follows:

a) Measurement of insulation resistance as a function of d-c voltage.
b) Measurement of the absorption current.
c) Measurement of the polarization index.
d) Measurement of ionization.

Visual observations are also very important.

Conclusions regarding the happenings in the system can be drawn from the changes in the measured values and can be derived from experience. For example, an occurrence of corona between the turn insulation and the slot insulation affects the aging. It can therefore be stated that corona will destroy the turn insulation at some time or other. This leads to a short circuit between the turns and subsequently to ground leakage. This case can hardly be simulated on the basis of a single test, but the results of aging can be easily constructed theoretically.

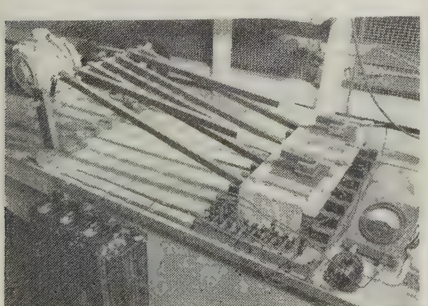

Figure 7, test arrangement for testing the frictional strength of corona protection paints.

Conclusions

When testing high voltage insulation a final test is indispensable. This is carried out by means of a model test, to simulate the service conditions, representing at least the essential cycle of operation.

It is useless to standardize such tests; it may even be dangerous because of the complex problems involved, because there are deviations in the test parameters, and because the test arrangement, the evaluation, and the judgement of the results depend, among other things, on the material to be tested and on the experience of the test engineer. The constructional details can also be of great significance. The financial outlay for such tests is heavy and experimental information often has to be bought dearly. The firms which carry out such tests only publicize their experience very hesitatingly, or not at all. Reproduction of the tests by a second person is very difficult. The new philosophy on the classification of insulation materials consequently demands the trust and confidence of the outsider in the correctness of the tests and their evaluation. A check on the suitability of the materials used with the help of a list, as was once possible for classification according to chemical properties, is inconceivable.

Appendix I

The dependence of life on the operating temperature of the test or equipment is given by

$$\log L = a + b \frac{1}{T}$$

L = life
T = temperature
a, b = constants

Appendix II

In Europe it is usual to view the power factor as a measure of corona in the system. Tan δ is measured as a function of the voltage and is then somewhat differently evaluated depending on the particular firm. The voltage at which the rise of the curve begins is designated as the corona inception voltage. The rate of rise of the curve, which is a measure of the corona intensity, is evaluated differently. The maximum rise in tan δ is used in the present report. The rise is given by

$$\frac{\Delta \tan \delta}{\Delta \text{ kv}} \text{ in } \%/\text{kv}$$

$(\tan \delta \times 100 = \tan \delta \ \%)$.

Acknowledgement

The author is grateful to Mr. Milan Moravec for carrying out the measurements and arranging the test setups.

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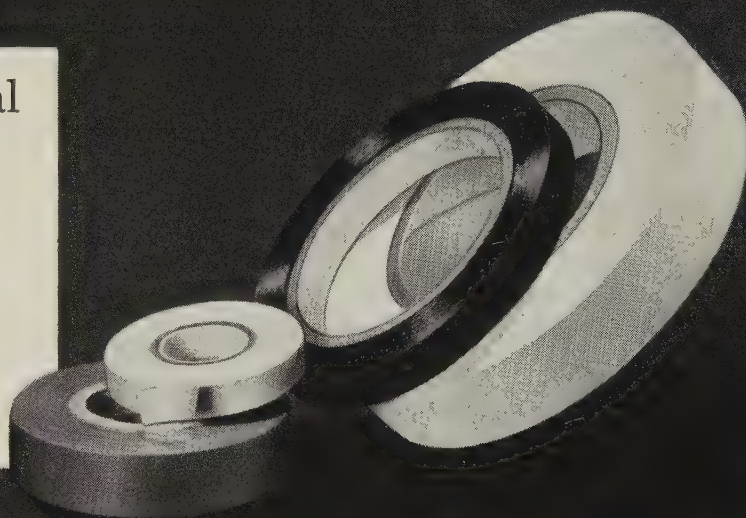

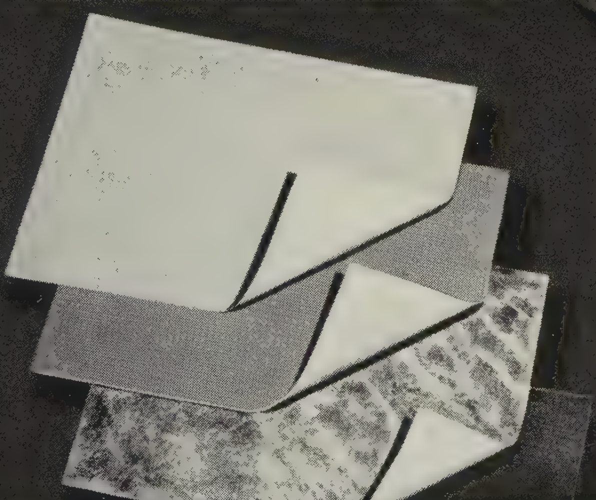

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Utilization of Unsaturated Polyester Resin For Small-Capacity Electrical Rotating Machines

By Wataru Koga, Makio Miyairi, and Tetsuo Ogawa, Yamazaki Works, Hitachi, Ltd., Japan.

Introduction

It is well known that unsaturated polyester resin in liquid state can be used for electrical insulation. Westinghouse has successfully utilized this material for stator coil insulation of generators. However, since curing of unsaturated polyester resin is affected by oxygen, curing of the air contacting surface is inhibited. This can be prevented by adding a small amount of paraffin or wax to the resin beforehand. The wax or paraffin is pushed out to the surface during the curing treatment and forms a thin film coating to prevent exposure to air and thus permit surface curing. Good results can be obtained in respect to electrical characteristics when this method is used, but adhesion between insulation coating layers is hampered in the case of multi-coats, which leads to separation of the insulation coating layers. Also, the coating property of unsaturated polyester resin is generally poor.

Owing to the above shortcomings, unsaturated polyester resin has been used very little as impregnating material for small-capacity electrical rotating machines.

Hitachi, Ltd. has recently produced an air drying type unsaturated polyester resin called "Polyset 202" for electrical insulation. The surface curing property and coating property have been improved. This product is being used for impregnation of coils of small capacity motors with resulting improvement of motor characteristics and reduction of cost.

This report deals with the results obtained in the characteristics test on "Polyset 202" and the life test by means of the motorette.

Characteristics

Properties of Polyester Resin

Table 1 shows an example of the test results on liquid resin. The film pick-up or build-up is about the same as that of conventional varnishes. However, a small amount of superfine silica powder should be added when a thick pick-up is desired with one coat. Table 2 shows the results of tests for adhesion and boiling resistance, in accordance with general varnish tests. The results indicate good adherence on metals and show that it is not affected after one hour boiling in water.

Next, the difference in electrical properties of resin plate and coated film were examined. The resin plate specimen of 2 mm thickness was made under the conditions given in table 3. Conductive paint was coated on it to serve as an electrode. The dielectric loss tangent was measured by a Schering bridge at 60 cycles and 1,000 v. The volume resistivity was measured by the d-c direct deflection method.

The coated film specimen having a thin coat thickness of 0.1 mm or less was made by flow coating and hung to dry. Therefore, some monomer evaporated. Then, the specimen film was formed under the conditions given in table 3 for three kinds of combinations differing in gel starting time and curing time. Tin foil was pasted on the film coat to serve as an electrode and the same tests were applied as in the case of the resin plates.

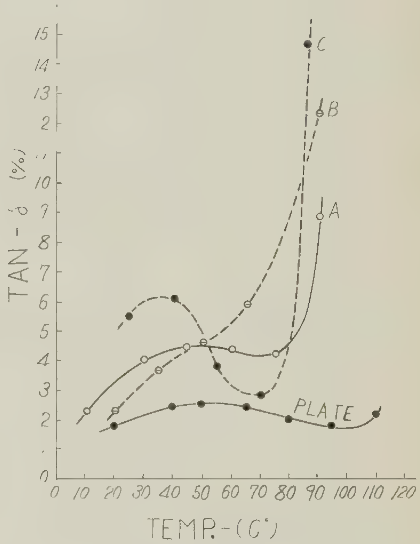

Figure 1, relation between dielectric loss tangent and temperature.

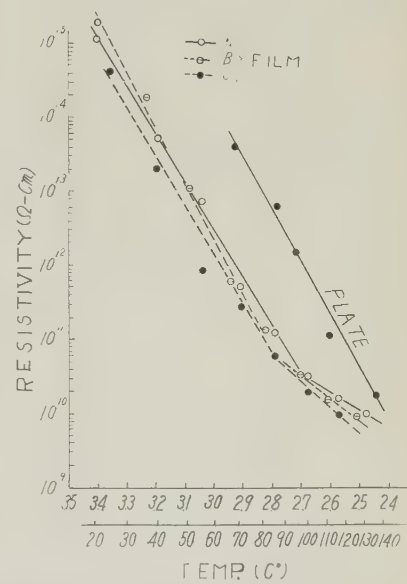

Figure 2, relation between volume resistivity and temperature.

Table 1, Example of Test Results on Resin		
Test	Value	Note
Color	<7	Gardner-Holdt
Viscosity, Poise at 25°C	1.2	Gardner-Holdt
Specific Gravity	1.076^{25}	Gay-Lussac's bottle
Acid Number	12	—
Solid content (%)	60	—
Stability	Good	—
Curing Properties		
Tack Free (hrs.) 25°C	1.7	Formulated for room temp. curing PT-20* 1% CT-3** 1%
Dust Free (hrs.) 25°C	4.0	
Pick up, middle part (mm)	0.04	
Gel Time		
CT-1* 1%	42 min.	G.E. Gel-timer at 80°C
CT-1* 2%	26 min.	
CT-1* 3%	21 min.	

*Promoter
**Catalyst

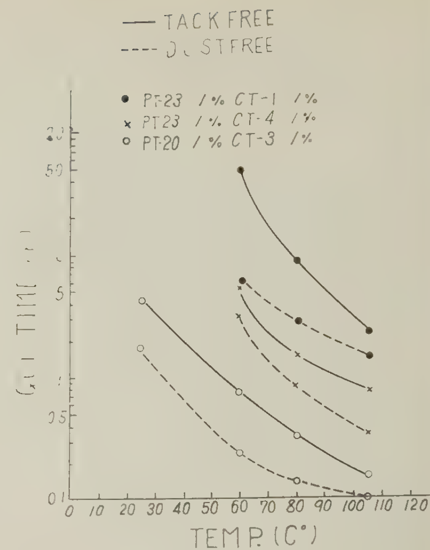

Figure 3, relation between curing temperature and curing time.

Table 2, Adhesion Property and Effect of Boiling in Water						
Curing Condition	Flexibility mm mandrel	Cross-cut Test (%)	Impact Gardner (kg-cm)	Scratch Hardness Test	Eritchsen Test (mm)	Effect of Boiling in Water
Room Temp. Curing, 3 days	3 ∅ OK	100	11.5	Passed	78	None
130°C—3 hrs.	3 ∅ OK	100	11.5	Passed	78	None

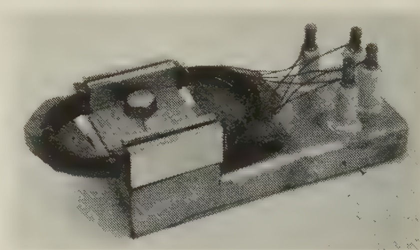

Figure 4, model motor used in motorette test.

Table 3, Method of Preparation of Motorette				
	Resin Plate	Coated Film Plate (A)	Coated Film Plate (B)	Coated Film Plate (C)
Polyset 202	100 parts by wt.	100 parts by wt.	100 parts by wt.	100 parts by wt.
PT - 20	1	1		
PT - 23			1	1
CT - 1				2
CT - 3	0.5	1		
CT - 1			2	
Curing Condition	60°C–2 hrs.→ 80°C–1 hr. → 105°C–2 hrs.	1st coat 60°C–1 hr. → 2nd coat 60°C–1 hr.→ 3rd coat 60°C–1 hr.→ 150°C–1 hr.	1st coat 105°C–2 hrs. 2nd coat 105°C–2 hrs.	1st coat 105°C–1 hr.→ 2nd coat 105°C–1 hr.

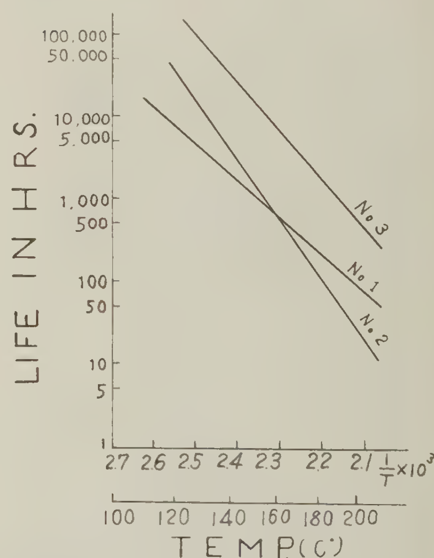

Figure 5, relation between temperature and life.

Table 4, Schedule of Heating		
Temp. (°C)	Class A	Class B
200±3	—	2
180±2	2	8
160±2	8	8
140±2	28	28
125±2	49	49

As can be seen, the characteristics of the resin plate and coated film plate differ noticeably.

The characteristics of the coated film are poorer because of changes in the cured resin due to evaporation of monomer. When the curing time is shorter, the monomer loss is less and consequently, the electrical properties are better . . . but the pot life is too short and this causes difficulty in processing. According to W. Gebhardt,[1] there is the following relation between film thickness, gel time, and percentage monomer evaporation: the amount of monomer which evaporates from a film of 45 μ thickness with 11 minutes gel time will be 77% at 11°C. Even when the film thickness is 175 μ, the loss will be 65% under the same conditions and will be 75% at 27°C. It is reported that the monomer evaporation is influenced mostly by the temperature and is not affected by the humidity in the atmosphere. When a small amount of wax is added to the film, as mentioned before, the monomer loss can be suppressed to less than 10% but it will be unsuitable as an electrical insulating impregnant. However, although monomer does evaporate, the portion which impregnates coil parts during actual coil treatment can be expected to have the same characteristics as the resin plate. Thus, there should be no problem.

Impregnation with Resin

Some methods of insulating treatment suitable for small capacity motors on the basis of preceding test results are as follows.

Room Temperature Curing Method

When a promoter and catalyst are used for room temperature curing, the pot life of the resin is short. Therefore, the following method is convenient.

First, prepare two mixtures, A and B. Mixture A will be stable for more than one month while mixture B will be suitable for about three days.

Mixture A: PS-202	100 parts
Promoter PT-20	2-3 parts
Mixture B: PS-202	100 parts
Catalyst CT-3	2-3 parts

Mix equal amounts of mixture A and B before use and apply by dip coating or brush coating. The amounts of the promoter and catalyst in the liquid mixture will be 1 and 1.5% respectively. Figure 3 shows an example of the relation between the curing temperature and curing time. If the curing time becomes too long, dust may adhere and soil the coating and the curing time will tend to become still longer due to the effect of moisture in the case of high humidity. Therefore, curing should be conducted with a temperature of 25°C or higher for practical purposes. The curing time can be greatly shortened by using the infrared ray lamp or air bath heating method.

Oven Curing . . . Method I

After mixing and dissolving with the following formula, apply the mixture by dip coating or brush coating.

PS-202	100 parts
Promoter PT-23	1 part
Catalyst CT-4	1-2 parts

In this case, the pot life will be 2 or 3 days at 25°C. Figure 3 shows an example of the relation between the curing temperature and curing time. This method has the disadvantage of a shorter pot life than the following method II but its curing time is short while the impregnated condition and electrical properties are better.

Heat Curing . . . Method II

After mixing and dissolving with the following mixture ratio and order, apply the mixture by dip coating or brush coating.

PS-202	100 parts
Promoter PT-23	1 part
Catalyst CT-1	1-2 parts

In this case, the pot life is 20 days or more at 25°C. Figure 3 again shows an example of the relation between the curing temperature and curing time.

Since the pot life is long, the liquid

Table 5, Check Voltage for Sequence Testing

Testing Part	Check Voltage (rms V at 50 cps*)
To Ground	600
Between Windings	600
Between Conductors	120

**Double the voltage specified by AIEE.*

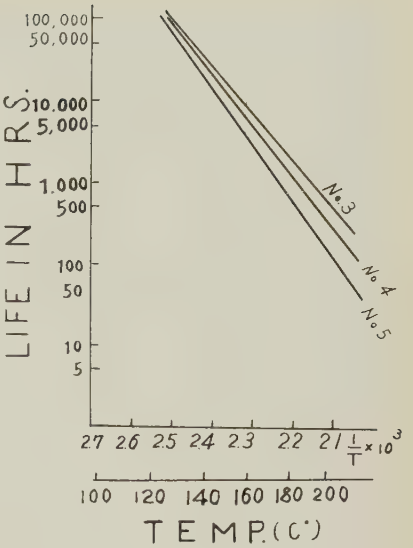

Figure 6, relation between temperature and life.

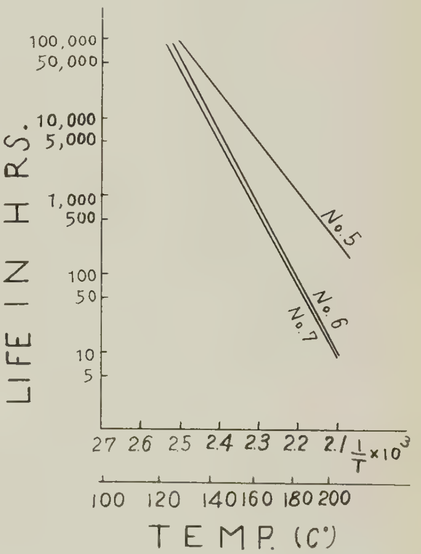

Figure 7, relation between temperature and life.

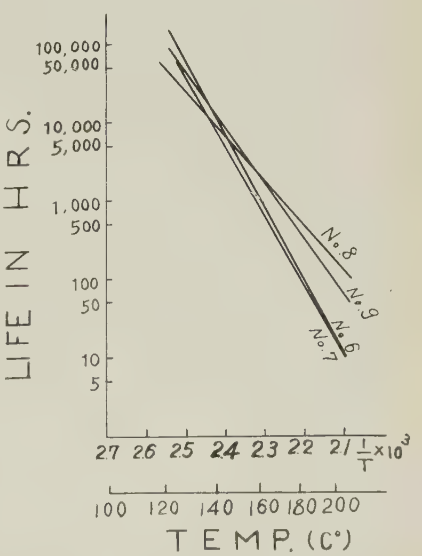

Figure 8, relation between temperature and life.

resin control is easier than in the above method I, but the impregnated condition and electrical properties are slightly inferior.

Evaluation of Life by Motorette Test

Testing Method

Specimen

A model motor, i.e., motorette, was constructed according to the test method specified by AIEE. The size of the model slot used in this test is the same as the slot of a 200v, 200W standard induction motor.

The insulation structure is the same as that of an actual motor. The only difference is, that in order to imitate a wire short circuit in the motor, two coils were wound in parallel in the motorette to check the breakdown voltage between coils.

Deterioration Promoting Method

The deterioration test was conducted with heating, vibration, and moisture absorption as one cycle. The heating time of one cycle is given in table 4. A mechanical vibration of 3,000 cpm frequency, 0.2 mm amplitude, and 1 g acceleration was applied in vertical direction on the coil surface immediately after 1 hour of heating. The motorette was left in for 3 days at constant temperature and constant humidity of 40°C and 70% RH for moisture absorption treatment.

Judgment of Life

Directly after the heating, vibration, and moisture absorption of one cycle, the test voltage given in table 5 was applied for 15 minutes. Failed motorettes were considered as having reached the end of their lives.

Coil Insulation Structure And Varnish Treatment

Three kinds of enamelled wires, i.e., polyvinyl formal wire, polyurethane wire, and polyester wire, having a conductor diameter of 0.6 mm and heavy coating were used as samples. A slot liner, consisting of "Mylar" film of 0.038 mm thickness and kraft paper of 0.25 mm thickness pasted together, was used for insulation to ground. For layer insulation, kraft paper of 0.13 mm thickness was used in the slot and pressboard of 0.25 mm thickness was used at the coil end outside the slot. The motorette having the above described insulation structure was given the varnish treatment listed in table 6.

Results of Life Test

First, the life test was conducted on samples Nos. 1, 2, and 3. The relation between the life and temperature obtained from the test results is shown in figure 5. Figure 5 shows that No. 3 has a much longer life than the other two. Since these three motorettes were considered as having class A insulation, the heating conditions for class A given in table 4 were applied. However, as the test progressed, it was found that motorette No. 3 had a much better heat resistance than the others. Therefore, in order to complete the test in a shorter time, the heating condition was changed to the class B test method (table 4) for sample No. 3 midway in the test.

This test alone is not sufficient to clarify whether the very long life of No. 3 is due to the use of polyester enamelled wire of good heat resistance, the unsaturated liquid polyester resin used as the impregnating material, or the vacuum impregnating treatment. In order to clarify this point, motorettes Nos. 4 and 5 were made exactly the same as No. 3 except that the treatment conditions were altered. The test results are shown in

*Table 6, Specifications of Atmospheric*** Pressure Impregnating Treatment for Motorette*

Treatment Specimen No.	Enamelled wire, 0.6 mm Heavy Coated	Impregnating Material	Drying or Curing (°C)	Mandrel Flexibility of Impregnating Material
1	Polyvinyl formal enamelled wire	Thermoset Varnish*A	120	120°C, 24 hrs., 3∅
2	Polyurethane enamelled wire	Thermoset Varnish**B	130	120°C, 24 hrs., 3∅
***3	Polyester enamelled wire	Polyset 202	80	125°C, 4 hrs., 3∅
4	"	Polyset 202	80	125°C, 4 hrs., 3∅
5	"	Polyset 202	105	125°C, 4 hrs., 3∅
6	"	Thermoset Varnish A	130	120°C, 24 hrs., 3∅
7	"	Thermoset Varnish B	130	120°C, 24 hrs., 3∅
8	"	Thermoset Varnish A	105 (Over baked)	120°C, 24 hrs., 3∅
9	"	Thermoset Varnish B	105 (Over baked)	120°C, 24 hrs., 3∅

**Phenolic:—Shot oil*

***Phenolic:—Medium oil*

****Note: Atmospheric pressure used for all specimens except No. 3 which was vacuum impregnated.*

figure 6. When the test results of Nos. 3 and 4 are compared, it can be seen that the effect of the vacuum treatment is quite apparent. That is, the motorette's life can be lengthened noticeably by increasing the varnish impregnating amount in the case of PS-202.

Sample No. 5 was given high-temperature, short-time drying treatment. The results of the test show that, to some degree, raising the drying temperature is effective in accomplishing sufficient curing.

Unsaturated polyester resin was used on polyester enamelled wire for each of the above motorettes Nos. 3, 4, and 5. However, motorettes Nos. 6 and 7 were made to study how the polyester enamelled coil is affected by the type of impregnating material. The results are given in figure 7. As seen in figure 7, Nos. 6 and 7 have a much shorter life than No. 5. However, the results of this test alone do not clarify whether such life differences are due to the effect of residual solvent on the polyester enamelled wire, or that the thermosetting type varnishes are basically unsuited for polyester enamelled wires. Therefore, samples Nos. 8 and 9 were made to study this point. They were made by drying (curing) for a long time to completely eliminate the residual solvent. Figure 8 shows the test results.

When compared with the test results for Nos. 6 and 7, it can be seen that the life at high temperature has been improved noticeably. The life curves of Nos. 6 and 7 intersect with the life curves of Nos. 8 and 9 at the low temperature zone. This indicates that the residual solvent has a detrimental effect, especially in the high temperature zone, and greatly shortens the life of Nos. 6 and 7 in the high temperature zone. For this reason, it would be dangerous to extend the life curve of the high temperature zone directly by a straight line to the low temperature zone. It can be considered that the straight lines of Nos. 8 and 9 indicate the actual life and that the straight lines of Nos. 6 and 7 have bent from the straight lines of Nos. 8 and 9 at the high temperature zone. In each case, the life is much shorter than when polyester resin was used. E. L. Brancato[2] has reported that initial breakdown will occur between wires in most cases when the heat resistances of the various insulating materials are balanced but will usually occur between layers and to ground when the heat resistances are not balanced. This tendency was observed in these tests also. Breakdown of insulation to ground occurred most often in the case of Nos. 7 and 8.

The results of the above tests indicate that the combination of polyester resin and polyester enamelled wire provides a longer life than other combinations.

Conclusion

Various tests were conducted on an unsaturated polyester resin which has good coating and air curing properties and flexibility.

Since there were no available reports for reference concerning this original trial application of liquid polyester as a coil impregnating material, final judgement was determined by a life test by use of a motorette.

1) The viscosity and pick-up property were the same as that for conventional insulating varnish. However, when a thick pick-up is desired, it is best to add a thixotropic agent such as super-fine powdered silica.

2) The pot life was examined for practical combinations of promoter and catalyst to obtain data for liquid resin control, and it has been explained that proper selection is required according to the purpose.

3) The electrical characteristics of resin plate differ from that of coated film plate. It was assumed that the characteristics of the latter were inferior to that of the former due to monomer loss.

4) According to the life test results by the motorette, a coil impregnated with the polyester resin has a much better heat resistance than a coil impregnated with a thermoset varnish.

Literature Cited

[1] *W. Gebhardt et al.: Farbe U. Lack 64 (1958).*

[2] *E. L. Brancato: Electrical Mfg. 63, 146 (March 1959).*

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New Developments in Epoxy Resins

Part 1 — What Is an Epoxy Resin? . . . and How Do You Specify One?

By Dr. Henry Lee, Technical Director, and Kris Neville, Project Engineer, The Epoxylite Corp., South El Monte, Calif.

Editor's Note: Electrical insulation involves a wedding of the two fields of chemistry and electrical engineering. Very few engineers or scientists working on insulation can claim a degree in both fields. Indeed, most insulation engineers or chemists are quick to admit that their schooling in insulation, per se, was rather cursory—their college training courses merely skirted the field and concentrated instead on electrical circuit design or organic synthesis, respectively.

With the growth of electrical insulation as a separate discipline, it becomes necessary for those who took their learning on one side of the fence to look over the fence and to learn to help bridge the fields.

One of the fastest growing facets of modern electrical insulation is that of electrical potting resins. For many years, these were tars and asphalts. They were regarded merely as substances to pour into a pot around a coil to prevent the entrance of moisture.

Today, with the concept of potting, embedding, and encapsulation being applied to larger and larger equipment . . . and smaller and smaller equipment . . . the demands on the potting compound are far more severe. The compound has become more of a structural element in the design of the component, and the utility of the potting compound enlarged from that of moisture protection to a much larger role.

Potting compounds now serve to protect equipment against an increasing range of chemicals, solvents, and mechanically destructive elements. The requirements of these applications cannot be met by older materials; and the introduction of newer plastics has resulted in a materials revolution that has only just begun.

The fastest growing class of plastics in the electrical/electronics potting field is probably the epoxy resins which have almost completely replaced polyesters and phenolics as potting and encapsulation compounds, and which are also making a strong bid as magnet wire insulation.

The success of modern insulation materials formulations (such as epoxy resin formulation) stems mainly from the concept of molecular engineering, wherein molecules of specific shape, size, and configuration are synthesized to meet the needs of the application. Such fields are outside the normal schooling of most electrical engineers.

Hence, *Insulation* is pleased to present a series of six integrated articles on this new and growing field of epoxy resins, prepared by members of The Epoxylite Corporation research staff and other experts in the field.

For those readers not familiar with polymer chemical symbolism, a table of principal symbols is included.

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The world of epoxy resins can be a confusing thing. There are hundreds

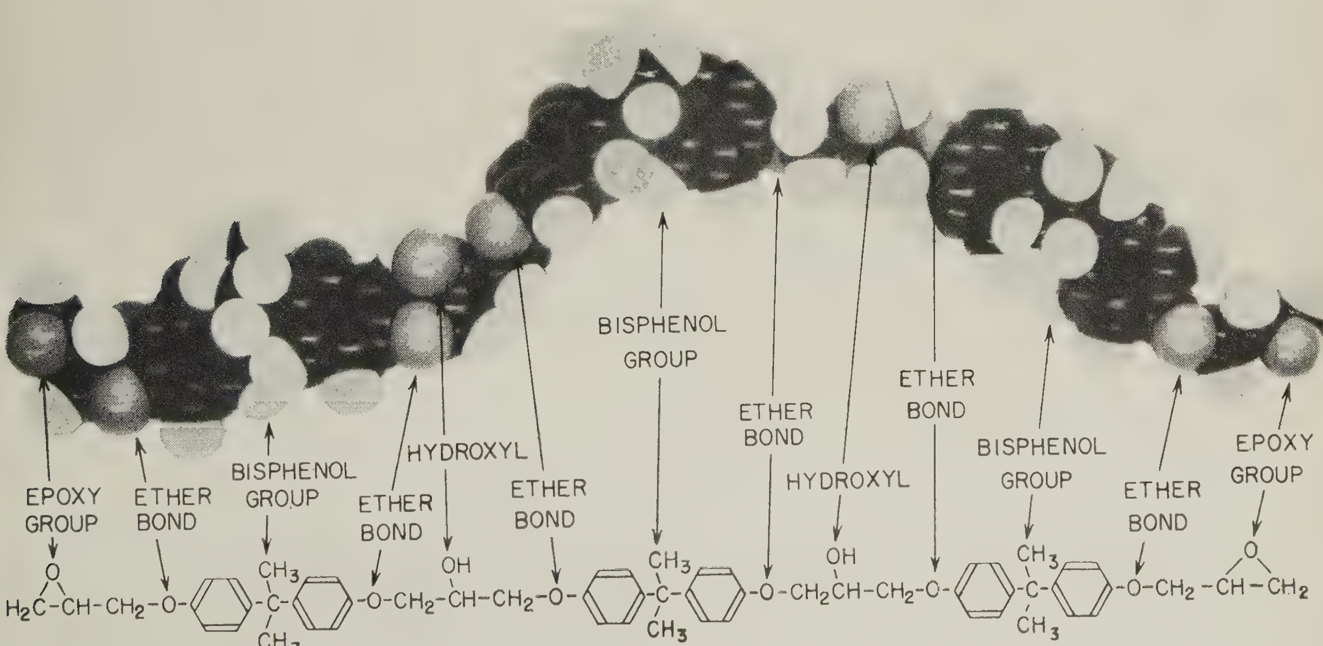


Figure 1, atom model of epoxy resin molecule compared with structural symbols (Diglycidyl Ether of Bisphenol A, Degree of Polymerization of 2). Magnification, approx. 100,000,000 times. Credit: Devoe & Raynolds Co.

of epoxy resins, epoxy resin compounds, and modified epoxy resins commercially available from numerous chemical and formulating companies, and from a seemingly endless number of distributors. And all of these are designated by proprietary trade names and numbers.

Trade names and numbers are convenient for the world of commerce, but they do not contribute to the scientific formulation and application of epoxy resins. Indeed, the plethora of numbers and the absence of chemical descriptions make it obvious that the term epoxy resin is becoming only a general chemical description, rather than representing a certain set of properties as was the case some years ago when only one or two of the first types of epoxy resins were introduced. This abundance of resin types gives rise to the question: "How does one select an epoxy resin for a given formulating requirement?"

Selection of an Epoxy Resin

The most basic procedure by which an epoxy resin may be selected scientifically is by the following steps:

1. Procure samples and technical data sheets of all epoxy resins offered commercially and developmentally by the 20 base chemical companies offering them.
2. Analyze the resins by various methods so that the generalized, if not exact structure, as well as molecular weight, equivalent weight, and molecular weight distribution are known.
3. Review the structures as to element content and chemical bonds (i.e., internal ether rings or bonds, carbon-nitrogen bonds, aromatic rings, etc.) with regard to the chemical resistance, and thermal stability required in the ultimate application.
4. Review the structures as to types of epoxy groups needed as dictated by curing considerations, such as room temperature cure or heat cure requirements, and curing agent considerations, which play a large part in determining the properties of the cured resin—i.e., acid resistance, alkali resistance, heat distortion temperature, thermal stability, etc.
5. Review curing agents themselves with regard to the above concepts.

This list of steps may sound idealistic or theoretical, since some simple epoxy fabrication problems can sometimes be solved by mixing resin X with curing agent Y from chemical company Z. However, in practice, where the real engineering advantages of epoxy resins are to be incorporated into the product, it is becoming increasingly more common to utilize a formulated compound manufactured by an epoxy resin formulator.

Role of Epoxy Resin Formulator

The epoxy resin formulator is a specialist in the development of epoxy resin-curing agent systems for specific applications. As such, he bridges the gap between the base resin supplier and the user. In practice, the base resin supplier is concerned with making as many millions of pounds of resins as he can per year from certain raw materials available to him. His research chemists must necessarily be concerned with studying new raw materials from which he can make new resins. His chemists must be long-

Table 1, Symbols of Polymer Chemistry —— A Handy Reference Glossary of Chemical Terms

Letter	Meaning	Letter	Meaning
| -C- |	Carbon atom. Normally needs four bonds either to adjacent carbons or to other atoms (hydrogen, oxygen, nitrogen, phosphorous, etc.)		
H-	Hydrogen atom (monovalent)	O ‖ -C \\ O / -C ‖ O	Acid Anhydride
-O-	Oxygen atom (divalent)		
-N<	Nitrogen atom (trivalent)		
P	Phosphorous atom		
S	Sulfur atom	O ‖ R' - C - O - R	Ester
R, R' R"	General purpose symbols meaning radical or group such as methyl, ethyl, etc. Often used to stand for the "rest of the molecule" so that attention can be focused on the reacting group.		
-OH	Hydroxyl group (alcohol)	H C // \\ HC CH | ‖ or HC CH \\\\ / C H	Benzene ring. Usually written as shown at the right.
O ‖ -C-	Carbonyl group		
O ‖ -C-OH	Carboxyl or organic acid	[CH_2 - CH_2]$_n$	Subfix n denotes that radical in bracket occurs a large number of times in repetition - thus leading to the term "polymer" from "monomer."
$-NH_2$	Primary amine	O / \\ -C - C-	Generalized epoxy group
>NH	Secondary amine		
-N<	Tertiary amine	O / \\ H_2C - CH - CH_2- O -	Glycidyl group type epoxy group
O ‖ C - N-H |	Amide		

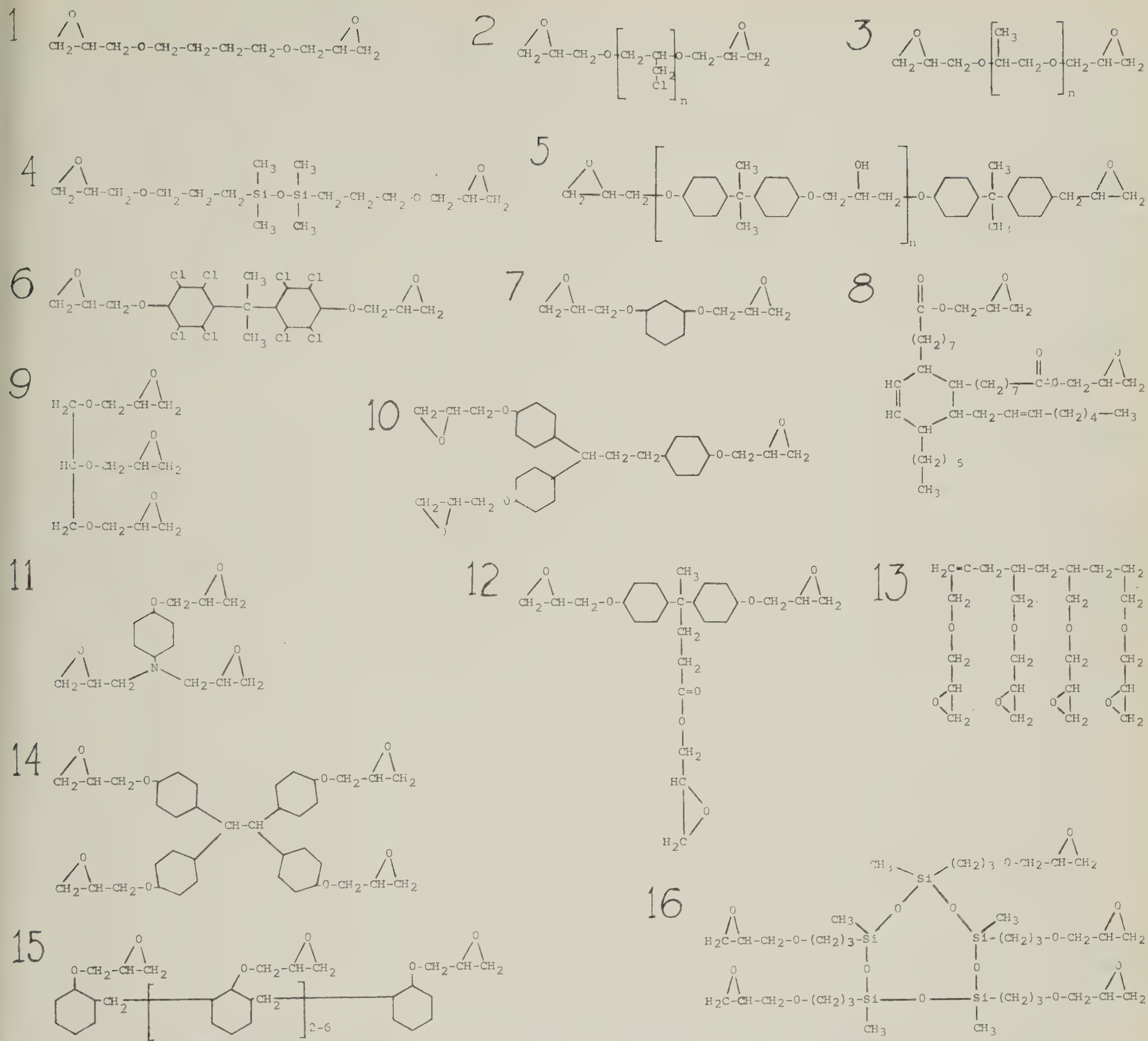


Figure 2, GLYCIDYL EPOXY RESINS: Diglycidyl Ethers, Aliphatic Based: *(1) Diglycidyl Ether of Butanediol, (2) Diglycidyl Ether of Polychlorohydrin, (3) Diglycidyl Ether of a Polyether, (4) 1,3-bis [3(2,3-epoxypropoxy) propyl]-tetramethyl disiloxane.* Diglycidyl Ethers, Aromatic Based: *(5) Diglycidyl Ether of Bisphenol A, (6) Diglycidyl Ether of Tetrachlorobisphenol A, (7) Diglycidyl Ether of Resorcinol.* Digylcidyl Esters, Aliphatic Chain: *(8) Diglycidyl Ester of Linoleic Dimer Acid.* Triglycidyl Ethers, Aliphatic Based: *(9) Triglycidyl Ether of Glycerol.* Triglycidyl Ethers. Aromatic Based: *(10) Triglycidyl Ether of Tri-hydroxylphenyl Propane.* Triglycidyl Mixed Ether and Amine, Aromatic Based: *(11) Glycidyl Ether, Diglycidyl Amine of p-amino Phenol.* Triglycidyl Mixed Ether and Ester: *(12) Diglycidyl Ether, Glycidyl Ester of 4, 4-bis (4-Hydroxy Phenyl) Pentanoic Acid.* Polyglycidyl Ethers, Aliphatic Based: *(13) Polyallyl Glycidyl Ether.* Polyglycidyl Ethers. Aromatic Based: *(14) Tetraglycidyl Ether of Tetraphenylene Ethane, (15) Epoxylated Novolacs (Based on Phenols and Substituted Phenols such as Cresylic Acid).* Polyglycidyl Ethers, Cyclic Aliphatic Based: *(16) Cyclic Silane Epoxy.*

haired and visionary, removed from mundane and pragmatic empiricisms of the final myriad uses of the product. On the other hand, the end user, such as electrical manufacturing company A, is interested in building as many KW per year of electrical components—all potted or encapsulated in epoxy resin when the application warrants—at the lowest cost and with the least confusion to members of his electrical engineering staff who are fighting the competitive battle of modern electrical and electronic hardware design. Under such conditions, he generally buys his steel, his magnet wire, his paint and varnish, and his epoxy compounds from other firms. He capitalizes on the electrical design ability of his engineering staff and on his electrical equipment production know-how. He is seldom interested in retaining a staff of chemists to formulate his steel, his magnet wire varnish, or his epoxy encapsulating compound. Indeed, it usually is not economical for him to

do so because manpower and overhead costs for such a department would far outweigh the dollar value of the materials he was purchasing. It is more profitable for him to let the steel manufacturer, or the wire varnish manufacturer, or the epoxy formulator take the research and development risk, and then to buy the best materials commercially available at a fair price. To formulate epoxy resins oneself; for example, to buy raw materials, study their usage, run quality control, compound the ingredients and process them into a formula, conduct quality control of the processed formula, and to maintain a staff of chemists to evaluate and study new raw materials, is grossly uneconomic until internal consumption exceeds a million pounds per year. Even then, with volume buying power as a good customer of a formulator, it may still be uneconomic to consider self-formulation. Indeed, self-formulation may realign an electrical company's entire manufacturing role. The company may find themselves pouring more money into basic formulation research than they may wish so that their encapsulated products compete with those encapsulated in the newest systems developed by the highly competitive formulators.

The Custom Formula And The Insulation Consultant

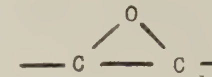
It is common practice for most electrical concerns to assign an electrical engineer to the role of insulation consultant. This consultant is or becomes a specialist in electrical insulations.

The design engineers refer to him for advice on all insulation problems. This consultant continually interviews insulation suppliers and epoxy resin formulators and keeps abreast of what types of new materials are available. Similarly, he relays to the technical staff of the formulator the specific design problems which the epoxy formulation must handle in the case of new electrical designs so that a custom formula may be developed if a standard one does not do the job. Such close cooperation and liaison is very effective and very economical in terms of development time and money. A typical case history of such cooperative development between the authors' company and a large electrical manufacturer will be presented in a subsequent article. However, at this time, it is desirable to review in detail some of the factors which the epoxy chemist must consider when selecting a resin, so that the insulation consultant and interested engineer are aware of the type of thinking and analysis which the epoxy chemist or formulator must perform when seeking to solve a resin system design problem, and will be aware of the strong points as well as the limitations of modern epoxy formulation technology.

What is an Epoxy?

"Just what is an epoxy?" is one of the most common questions interested electrical engineers ask.

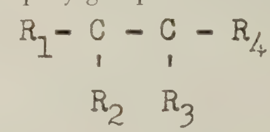
Chemically the term epoxy means a three-membered ring containing one oxygen and two carbon atoms arranged as follows:



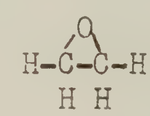
An epoxy *resin* is a molecule which contains, on the average, more than one of these groups.

The epoxy structure is uncommon in nature except as an intermediate. The angles required to form such a small ring induce great strain on the interatomic chemical bonds, making the ring highly reactive. Nature prefers five- and six-membered rings, which, correspondingly, are more stable.

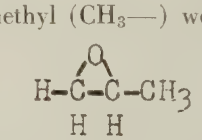
It is useful to examine the nomenclature involving the epoxy ring before treating epoxy resins, per se, directly. Because carbon atoms are generally tetrafunctional, the complete and proper generalized structure for an epoxy group should be shown.



In this generalized epoxy group R_1, R_2, R_3, and R_4 are hydrogen atoms or substitutions of organic radicals. If the four radicals are all hydrogens, we have



ethylene oxide, a highly reactive gas. If R_4 is methyl (CH_3—) we have



propylene oxide, another reactive gas.

Examining the epoxy group fur-

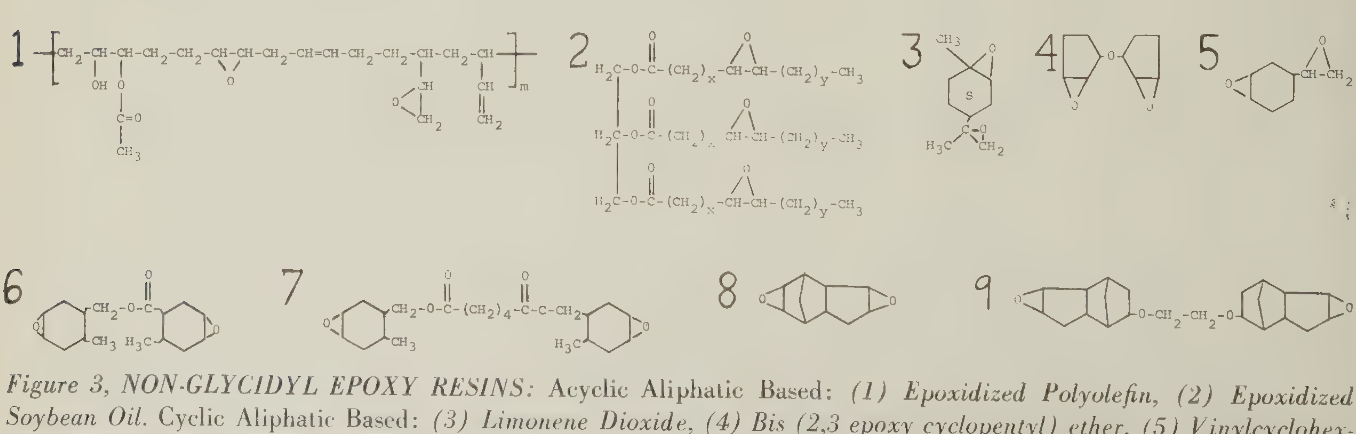


Figure 3, NON-GLYCIDYL EPOXY RESINS: Acyclic Aliphatic Based: *(1) Epoxidized Polyolefin, (2) Epoxidized Soybean Oil.* Cyclic Aliphatic Based: *(3) Limonene Dioxide, (4) Bis (2,3 epoxy cyclopentyl) ether, (5) Vinylcyclohexane Dioxide, (6) 3,4-Epoxy-6-Methylcyclohexyl Methyl-3,4-Epoxy-6-Methyl Cyclohexanecarboxylate, (7) Bis (3,4-epoxy 6-methyl cyclohexylmethyl) Adipate, (8) Dicyclopentadiene Dioxide, (9) Bis Epoxy Dicyclopentyl Ether of Ethylene Glycol.*

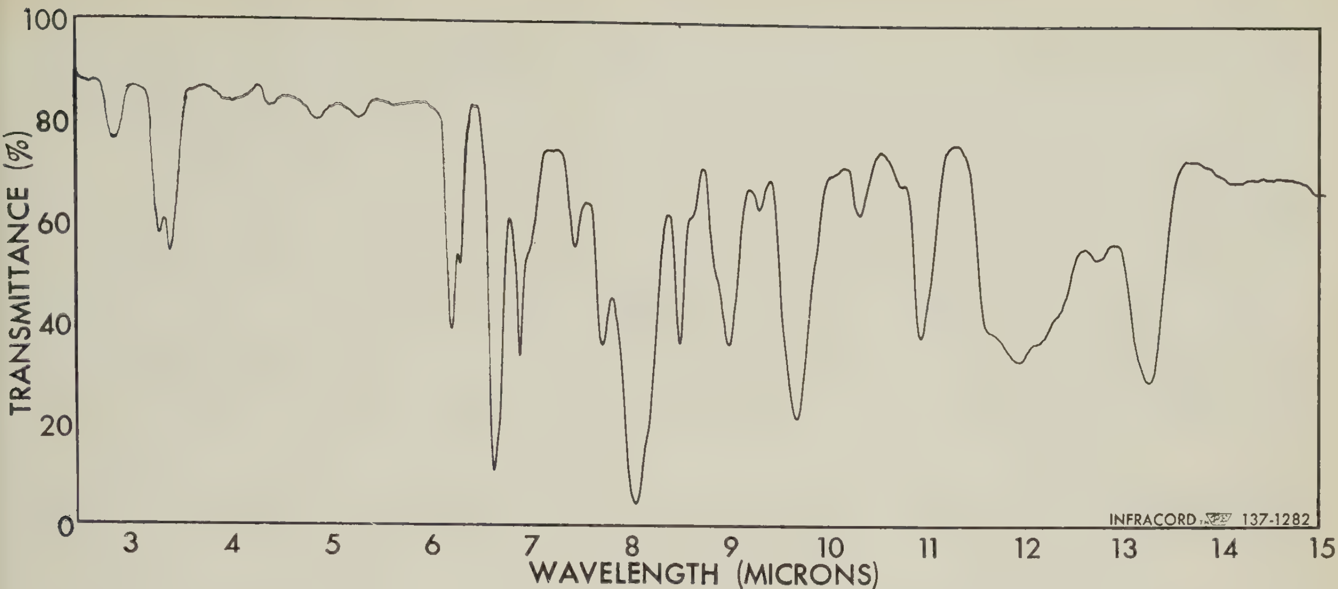
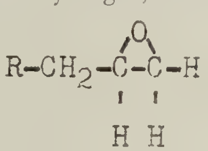


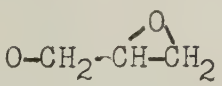
Figure 4, infrared absorption spectrum of an epoxy resin. Infrared is a useful tool in analyzing the structures of epoxy resins. The various atomic bonds within a molecule possess characteristic vibration frequencies. Measurement of these frequencies (or their wave length) permits identification of the bond composition of a molecule, and hence its structure. Also, the infrared technique provides amazingly accurate quality control. In addition, comparison of resin structures and/or their infrared spectra permits an assessment of polarity (dipole moments) and polarizability, factors which are necessary for estimating Van der Waal's forces, the short range intermolecular forces which are most important in determining mechanical strength vs temperature, solvent resistance, and compatibility of the resin with various curing agents and modifiers.

ther, if R_1 is a methylene group (R—CH_2—), containing some other as yet undefined substitution, and the other radicals are hydrogen, we have



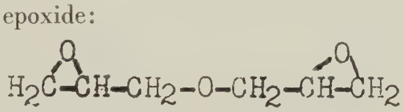
which is defined as a substituted glycidyl group. Depending on the nature of the R, this molecule may be either a gas, a liquid, or a solid. Similarly its chemical reactivity will depend on the substituted radical.

The addition of an oxygen beyond the glycidyl radical gives

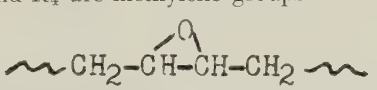


a glycidyl ether radical. The electronegative nature of the oxygen exerts a strong effect upon the strained, three-membered ring. It produces a marked change in the solubility, chemical resistance and reactivity of the epoxy group as will be discussed subsequently.

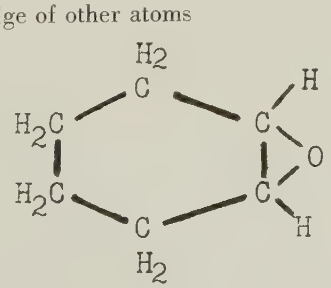
Many commercial epoxy resins contain a plurality of these glycidyl ether groups, the simplest example of which would be diglycidyl ether, a basic diepoxide:



But this by no means exhausts the possibilities for an epoxy resin. Returing to examination of the substitutions on the epoxy ring, if both R_1 and R_4 are methylene groups



then the epoxy group is considered to be internal rather than terminal and is located along the "inside" of a chain rather than at its end. If in the generalized structure, R_1 and R_4 happen to be connected through a bridge of other atoms



then we have the epoxy-ring situated on another ring.

On the basis of the preceding short descriptions, it may be concluded that numerous chemical structures, all containing epoxy groups, are possible. But just what constitutes an epoxy resin?

Definition of Epoxy Resin

An epoxy resin may be defined as any molecule containing more than one epoxy group. The groups may be glycidyl, terminal, internal, ring situated, etc., or combinations of any of these. This definition is often modified in practice by adding the qualification . . . "and which is capable of curing or reacting to a hard, tough, durable solid." This qualification is considered to stem from older connotations wherein the natural resinous products—shellac, amber, rosin, etc. — were mostly hard solids initially. To some extent this connotation is still useful in that some diepoxides, when cured, do not develop the good strength of others (due to steric hindrances to cure, for example) and as such are more suitable as diluents for other epoxy resins. However, for the purpose of convenience, all di- or poly-epoxy molecules will be referred to as epoxy resins in this article, since this is common practice in the field.

Commercial Epoxy Resins

On the basis of the numerous generalized structures drawn above, it may be assumed that there are numerous types of diepoxides referred to generically as an epoxy resin. This is indeed the case.

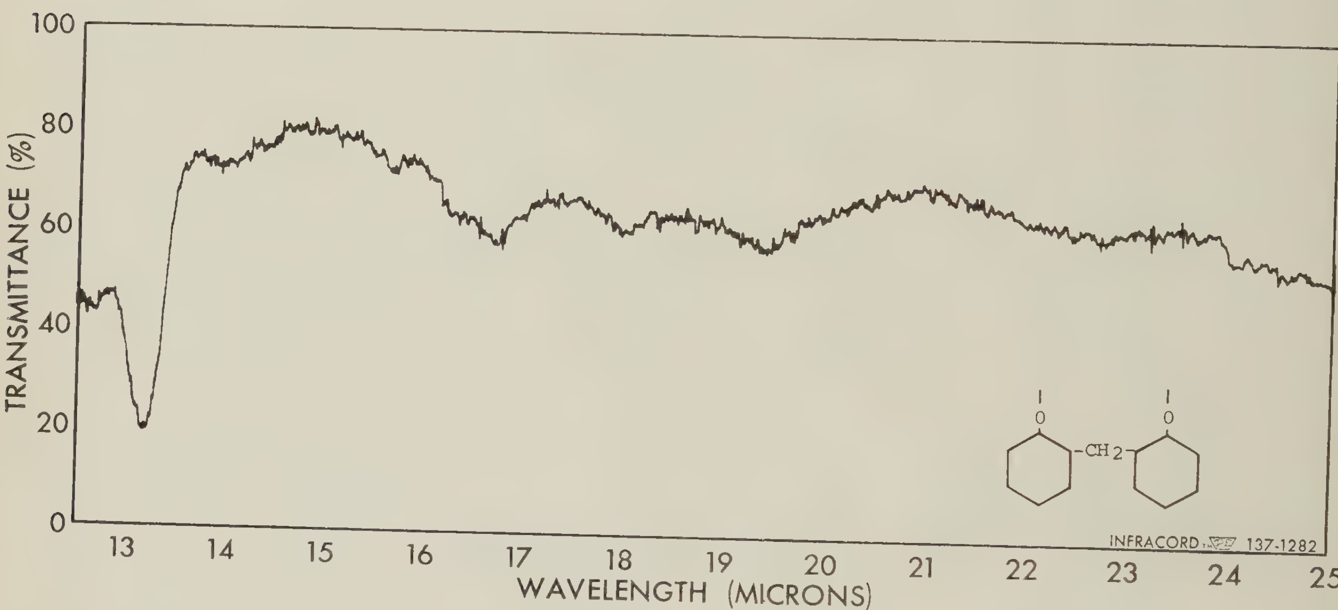
There are 25 different *types* of epoxy resins available today, commercially or experimentally, from 20 base chemical sources. These are presented graphically in figures 2 and 3. Many of these resin types are also available as higher molecular weight homologs or higher molecular weight condensation derivatives of the base types (e.g., in figure 2, resin type 5, where n is greater than zero, a range of molecular weights of resins are available). Thus, in all, about 75 base epoxy resins are available with which the epoxy chemist can work.

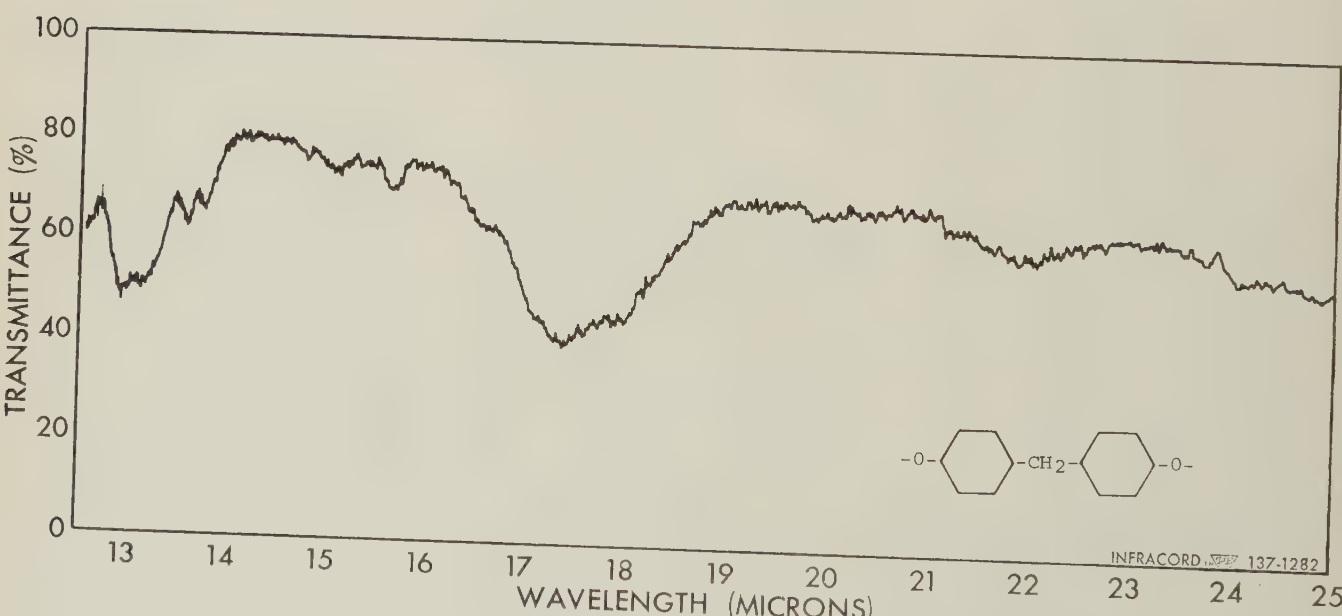
These many resins are but building blocks in the development of an epoxy resin compound. An epoxy resin compound—or formulation—involves one or more epoxy resins, curing agents, and modifiers such as plasticizers, flexibilizers, accelerators, stabilizers, flow control agents, pigments, and selected fillers which modify various properties further.

At this point let us examine how an epoxy chemist selects an epoxy resin for formula development work.

Chemical Structure of Commercial And Developmental Epoxy Resins

Figures 2 and 3 present idealized or





Figures 5A and 5B, far infrared spectra of two epoxy resins. The far infrared spectrum normally reveals the rotational spectrum of a molecule. Its rotational moment is the key to whether the molecule is based, for example, on a para-bisphenol or an ortho-bisphenol, which is important chemically in determining reaction rates and steric factors. Raman spectroscopy, which may be used to determine the polarizability of a molecule (and which, in conjunction with the dipole data from infrared and rotational data from far infrared, characterizes the resin in terms of bond angles, bond distances, masses, and mass displacements) is difficult to run on epoxy resins because of fluorescence effects which mask the low energies of the Raman shift.

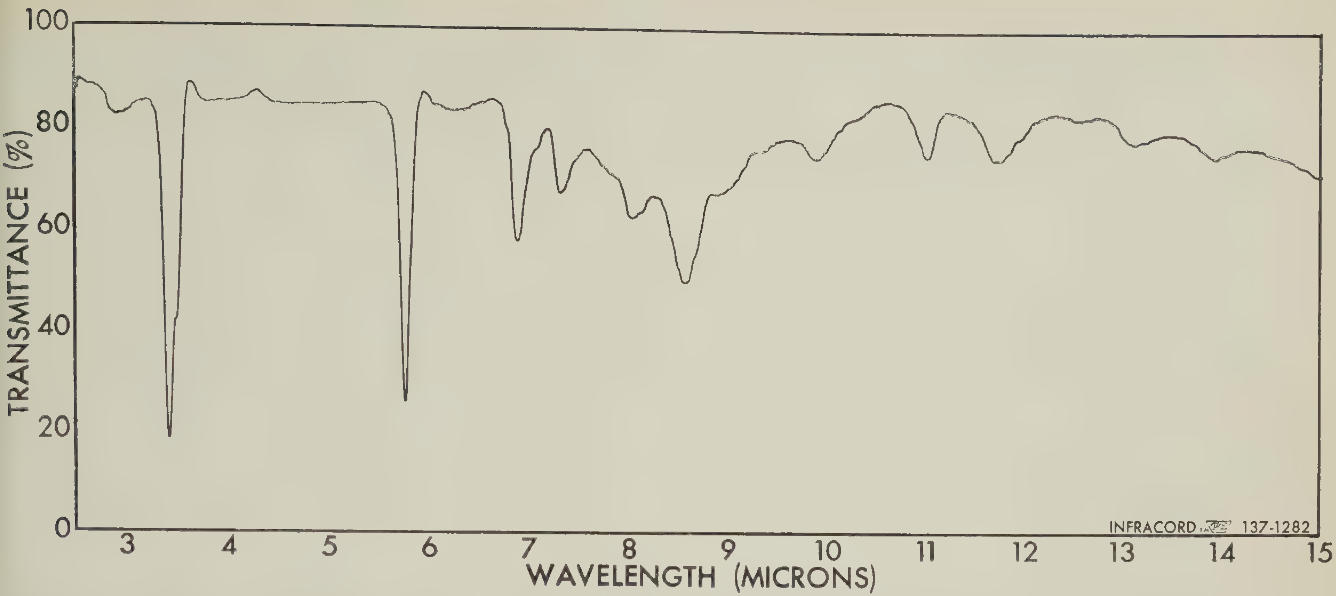


Figure 6, infrared absorption spectrum of an epoxy resin having low dipole moment, as contrasted with resin shown in figure 4. A blending of these two resins would result in a varied range of dipole moment, polarizability, Van der Waal's forces, and crosslinkage density. The effect on properties is shown in figure 7.

theoretical structures of epoxy resins commercially available in the U. S. as well as a number of developmental resins. The structures are believed to be representative. They are based on disclosures in the trade literature and in the patent literature, as well as analysis by infrared spectroscopy in the authors' laboratory. Because of patent and other proprietary considerations, only chemical names are disclosed; commercial designations are not presented.

Chemical Constitution Of the Resin Chain

Chemical constitution of the resin chain involves numerous concepts. Primary ones are heat stability, solubility, and chemical resistance. For example, carbon-carbon bonds in an aliphatic chain are not as heat-stable as carbon-carbon bonds in an aromatic ring. Similarly, an aliphatic chain (resin 8 in figure 2) will swell or dissolve in aliphatic hydrocarbon solvents, whereas an aromatic group, (resin 7 in figure 2) will resist solvation by such solvents. Another example would be the possibility of limited heat stability of an aliphatic carbon-nitrogen bond (resin 11 in figure 2). And both of these bonds would be inferior to an ester linkage (resin 6 in figure 3). However, conversely, the ester linkage would be the first attacked by an alkaline medium such as potash or caustic soda or ammonia vapors in a high humidity environment. The requirements of heat stability would have to be balanced against those of chemical resistance, in such a case.

Another way of describing the importance of chemical composition, in the language of the physical chemist, is in terms of polarity and polarizability. These are outlined briefly in figures 4, 5, and 6.

Type, Location, and Number of Epoxy Groups

The type of epoxy groups in a resin (figures 2 and 3) is important insofar as they determine what type of curing agent may be used with what resin. They also determine whether heat cure will be required, or whether sufficient exothermic energy will be given off by the reaction of the epoxy and curing agent to drive the cure to a satisfactory degree of completion. In general, very definite reactivities exist among the various different types of epoxy groups, some types preferring electrophilic curing agents, others nucleophilic curing agents. Electrophilic substances are those which react with the epoxy ring by attacking the oxygen atom and straining its bonding to one of the carbons so as to break the bond open and to allow the atoms of the curing agent to establish new bonds with the atoms initially in the epoxy group. A nucleophilic substance is one which prefers to attack the carbons in the epoxy group, rather than the oxygen. To do this, the curing agent must be able to get behind the carbons on the side of the epoxy group away from the oxygen. Obviously, then, the location and type of epoxy group is important. Terminal groups may most readily be attacked by both types since they are exposed. Ring situated groups may most easily be attacked by electrophilic curing agents, and are almost unreactive with nucleophilic reagents because the chemical ring on which the epoxy group is located prevents the curing agent from approaching the backside of the epoxy group. In addition, the presence of oxygen atoms or aromatic groups adjacent to the epoxy group can markedly influence the reaction rate of a given type of epoxy group, so that all in all, the curing of epoxy resins is one of great complexity.

The number of epoxy groups in a molecule may be referred to as the molecule's epoxy functionality. A resin with many epoxy groups provides more reactive sites than a similarly sized molecule with fewer epoxy groups does (resin 7 vs resin 11 in

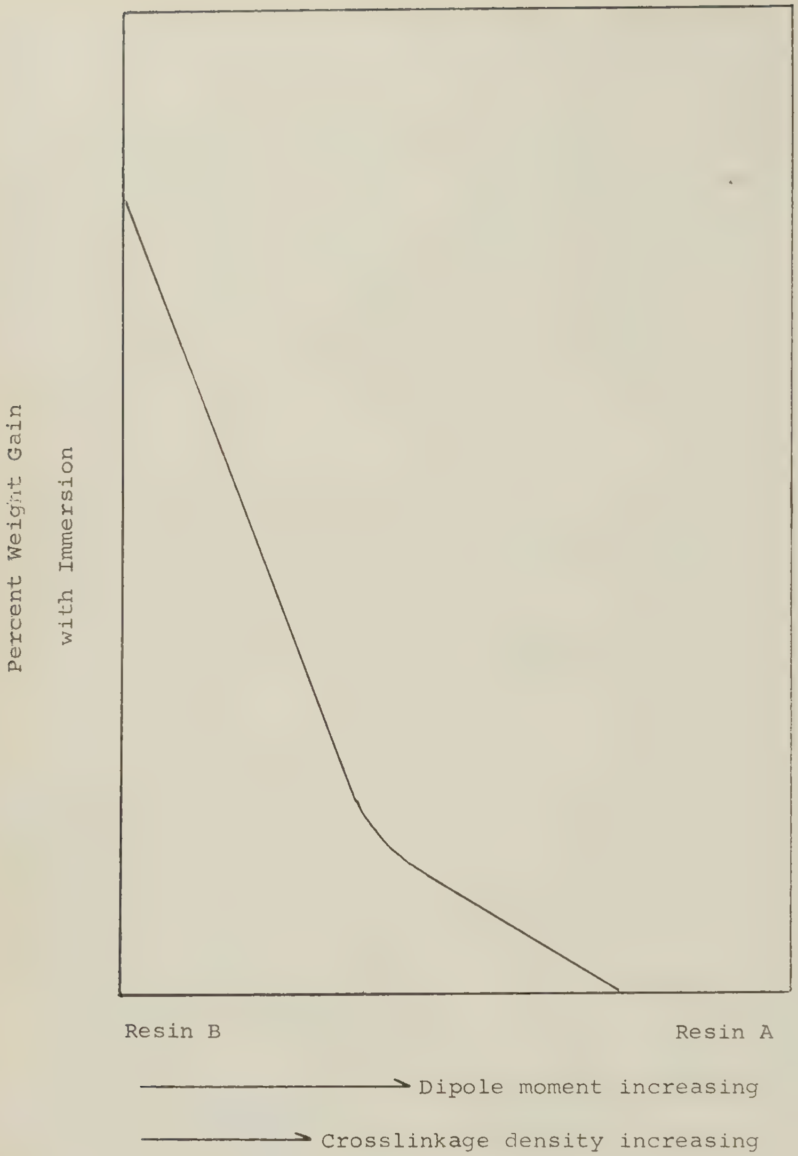


Figure 7, effect of resin composition (synthesized by blending) on resistance to a non-polar solvent. High dipole moment in the chain as well as tight crosslinking result in high resistance to this type solvent. Such studies have produced compounds suitable for prolonged exposure to boiling (with reflux at 240°F), gasoline, and jet fuels.

figure 2.). When cured, a resin with high functionality will have a higher crosslinked density. Crosslinked density means the number of primary chemical bonds in a given volume of space occupied by the cured resin.

Distance Between Epoxy Groups

Thus, crosslinked density for a given sized molecular chain is a function of the number of epoxy groups attached to it. However, between different resin types, the chain distance between epoxy groups becomes an important factor. In the case of diglycidyl ether, the two epoxy groups are separated by only three atoms. In the diglycidyl ether of bisphenol A, the epoxy groups are separated by seven atoms (the aromatic ring is counted as one unit only). In other resins, the epoxy groups may be separated by as many as 30 or 40 atoms. Short spacings (3-10 atoms) mean rigidity or brittleness, medium spacings (10-30 atoms) mean semi-rigid properties, and long spacings (30 atoms and over) mean flexibility or softness. Between resin types, these approximate spacings will shift because of temperature effects. That is, materials with low dipole moment genreally have low Van der Waal's forces, and high coefficients of thermal expansion. Hence, at a given temperature, less chain lengthening is needed for an aliphatic based resin than for an aromatic based resin to produce a given softness or flexibility. If comparisons between resins are made at elevated temperatures, where Van der Waal's effects have been reduced, then the effect of differences among chain compositions are reduced, and the flexibility and other properties more closely follow the above mentioned chain length and crosslinkage distance concepts.

Presence of Other Reactive Groups

A number of epoxy resins also possess reactive groups other than epoxy groups. These groups include hydroxyl groups (resin 5 in figure 2), olefin groups (resin 1 in figure 3), and vinyl groups (resin 1 in figure 3). Since some curing agents are capable of reacting with these other groups as well as with the epoxy groups, the presence of these groups must be reviewed in light of crosslinkage density, and the possibility of detriment to the cured resin if these groups are not consumed. Maleic anhydride is an example of a curing agent capable of reacting with epoxy groups, hydroxyl groups, olefin groups, and vinyl groups, if proper catalysts are present. Hence, cure mechanisms can become quite complex. However, if vinyl or olefin groups are left non-reacted, these groups are obvious sites for oxidation attack under even only mild thermal abuse. Since some resins also contain catalytic centers (resin 11 in figure 2), the problem is further complicated.

Once the basic resin has been reviewed, then the potential curing agents must be reviewed in regard to their functionality and their distance between reactive sites, and in regard to their chemical chain makeup and hence heat stability, solubility characteristics, polarity, etc. The problem of curing agent selection will be discussed in the next article.

Reference

Lee and Neville, "Epoxy Resins—Their Applications and Technology," McGraw-Hill Book Co., New York, 1957.

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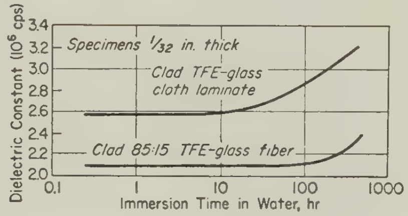
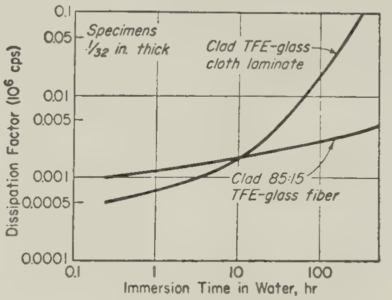
Def under load (300 F), %		
1200 Psi	4	0.4
2000 Psi	25	1.0
Ther Exp Coef (73-140F), 10^{-5}/F	5.5	1.6, 5.0*
Heat Distortion Temp, F		
66 Psi	250	500+
264 Psi	—	500+
Dielec Const, 10^6 Cps	2.00	2.2

*Longitudinal and transverse, respectively



Effect of water immersion on dielectric constant.



Effect of water immersion on dissipation factor.

SUMMARY OF ADVANTAGES

Close tolerance thickness control . . . excellent machineability, punchability . . . uniform electrical characteristics . . . excellent dimensional stability over wide temperature range . . . lower coefficient of expansion and reduced cold flow compared with Teflon . . . no "window" effect . . . no wicking.

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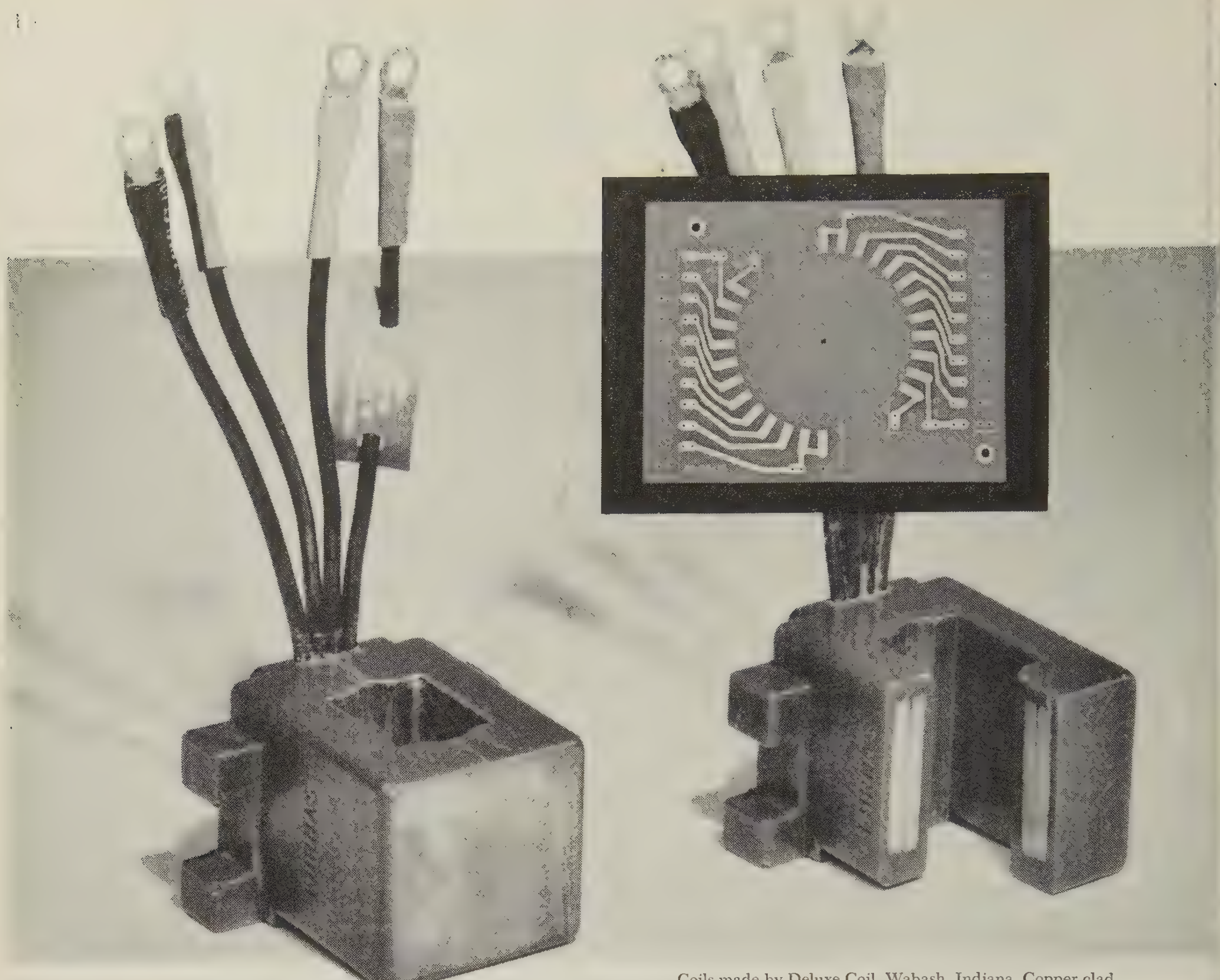

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Review of Papers Presented at October Conference on Electrical Insulation

Test Methods and Measurements, Radiation, Electrical and Physical Properties, Gassing, and Filler Influences Are Covered

As in past years, *Insulation* is again pleased to publish summaries of some of the important papers presented at the annual Conference on Electrical Insulation of the Division of Engineering and Industrial Research, National Academy of Sciences-National Research Council. This year, the meeting was held at the National Bureau of Standards, Washington, D.C., on October 17-19. About 200 members and guests attended. Four round-table discussions were held, and 27 technical papers were presented.

New officers were elected. They are: S. I. Reynolds, General Electric Co., chairman; Philip Franklin, Diamond Ordnance Fuse Laboratory, vice chairman; and J. Sticher, Detroit Edison Co., secretary.

It was decided to hold the 1961 conference in Pocono Manor, Pa., on October 23-25. Also, the 1962 conference dates were set for October 15-17, in Hershey, Pa.

The summaries that follow are on such subjects as electric breakdown in n-hexane, radiation degradation of polyethylene terephthalates and polyvinyl halides, gamma radiation induced conductivity in solid insulation, theoretical limitations on the properties of dielectric liquids, Townsend ionization constants in n-alkanes, reactions of active nitrogen with polyolefins, hygroexpansivity of cellulose papers, electrical properties of some solid organic esters, electrical surface failure in the presence of conducting liquid contaminant, and residual losses in a guard-ring micrometer-electrode holder for solid-disk dielectric specimens.

Also, influences of metallic fillers on the properties of epoxy plastics, novel resonant cavity techniques for evaluating artificial dielectrics, gassing properties of aromatic hydrocarbons, dielectric properties of glasses, a liquid displacement test method for determining the anisotropic dielectric properties of printed wiring boards, an ultra low frequency bridge for dielectric measurements, and the thermal degradation elevator effect.

Unfortunately, the need for advance availability of papers makes it impossible to review all of the excellent and interesting papers that were presented.

Electric Breakdown in n-Hexane

By A. M. Sletten, Insulation and Chemicals Dept., Materials Laboratories, Westinghouse Electric Corp.

Electric breakdown and conduction in organic liquids has been the subject of reintensified investigation in recent years. But even in highly purified test liquids, such as n-hexane, the experimental evidence is still subject to continuous alteration and improvement. Failure to reproduce earlier measurements of breakdown strength in n-hexane led to the discovery of the importance of dissolved air or rather oxygen in the test liquid.

The discovery prompted this investigation, which deals mostly with the effect of dissolved gases on the electric strength of n-hexane.

The electric strength of n-hexane as measured with direct test voltage and a uniform field gap arrangement is found to increase from $\sim$0.7 MV/cm in a thoroughly degassed liquid to $\sim$1.3 MV/cm when the oxygen content of the test liquid is increased to about 100 mm Hg partial equilibrium pressure. Spherical stainless steel electrodes with 1 cm diameter and a gap length of 50μ (2 mils) were used.

Further increase in the amount of dissolved oxygen does not further increase the measured electric strength. Tests indicate that the effect of dissolved air on the breakdown is due to the effect of oxygen alone. No effect on the electric breakdown was found when dissolving nitrogen alone in n-hexane. The electric strength remained at about 0.7 MV/cm as for a degassed liquid.

The breakdown strength was found to be cathode dependent. An oxidized aluminum cathode gave consistently lower strengths than a stainless steel cathode.

The test gap was kept under constant observation through a microscope giving approximately X120 linear magnification. With suitable illumination it was estimated that particles down to 1μ diameter could be observed. Despite many efforts to improve purification, particles were always visible in the gap. In some cases a particle on the cathode surface was observed to cause conduction currents several magnitudes higher than normal, but usually no correlation between particles and breakdown strength could be found.

With a gap length of 75μ and high oxygen contents (340 mm Hg), however, the visible particles were sometimes observed to be ejected from the high field region of the test gap by the returning electric field following a breakdown. The electric field could in that case sometimes be increased to 2 MV/cm before breakdown occurred, but usually an occasional returning particle would cause immediate breakdown below this value. The above phenomenon was also observed when using n-hexane with a high content of carbon dioxide at a gap length of 50μ.

Radiation Degradation of Polyethylene Terephthalates And Polyvinyl Halides

By L. M. Epstein, Radiation and Nucleonics Laboratory, Westinghouse Electric Corp.

"Videne" A is chemically very similar to "Mylar" polyester film but is intended for laminating and other processing applications. To compare the radiation effects, 2 mil samples of Videne A and 0.25 mil Mylar were irradiated simultaneously in air. The irradiations were carried out with 2 MEV electrons from a Van de Graaf accelerator. Since radiation damage is evident much sooner in the mechanical properties than in the dielectric strength, tensile tests were performed.

The results are—for Mylar—in very close agreement with previously published results which were obtained with nuclear reactor irradiation (fast neutrons and gamma rays). The rate of damage for Videne A is clearly much greater. However, it is also clear from the non-irradiated properties that the two materials are physically quite different.

It was of interest to determine whether the increased rate of physical degradation of the Videne was due to any inherent chemical weakness. This was done by determining the reduction in molecular weight upon irradiation, as estimated from the solution viscosity. The results reveal the following: a) although the original Mylar had twice the molecular weight of Videne A, it degraded very rapidly at first whereas Videne A stayed nearly constant; b) after the initial radiation dose materials were closely similar in molecular weight and remained so, and c) air had a minor effect.

Thus, as far as chemical changes are concerned the Videne A appears equally as radiation resistant as the Mylar. It is believed that Mylar's retention of strength despite chemical damage is a consequence of its very high degree of molecular orientation.

High quality polyvinylfluoride film ("Teslar") is analogous in chemical structure to polyvinylchloride, with fluorine substituted for chlorine. Physically, polyvinylfluoride (PVF) is superior in its ability to be drawn into thin strong films, and chemically it is said to be superior in its resistance to heat and ultraviolet light.

Radiation effects on polyvinylchloride (PVC) have been studied extensively. Despite some controversy over the exact nature of the chemical changes which occur it is generally agreed that most formulations retain a good measure of their physical properties up to about 10^8 rads, and hydrogen chloride is evolved in substantial amounts, constituting the most serious objection to the use of PVC in radiation fields.

Superficial examination of irradiated PVF film indicated that it retained its physical properties at least as well as PVC. Anticipating that PVF would also yield acid, samples of the two materials were irradiated under identical conditions, and the acid evolution measured. (The PVC used was commercial material purified by reprecipitation, so as to be free of plasticizers and stabilizers. For PVF, Teslar film was used as received.) It was found that, despite the difference between the two runs (made under different conditions), the acid evolution was almost identical for the two polymers.

Not only is acid evolution detrimental per se, but it was suspected that the radiation-damaged polymers might have reduced heat stability as well. Accordingly, the irradiated samples from the second run were heated to 98.4°C, each in a small tube leading to a water trap, and the acid evolution measured from time to time. Along with the irradiated samples, several non-irradiated samples of each material were aged. None of these evolved any acid in over 30 days.

In the case of PVC, the initial rate of thermal acid evolution is proportional to the radiation dose received, but this rate tapers off as the degradation proceeds (the maximum acid obtainable is 16 milli-equivalents/gram).

In the case of PVF, all the samples regardless of dose showed the same sudden evolution of about 11 milli-equivalents/gram about the third day. (The maximum PVF is 21.7.) It is believed that under the conditions of limited access of air, a free radical "unzipping" of HF takes place very rapidly. The fact that only about half, and not all, of the possible HF comes off can be explained by the presence of blocking groups and the randomness of the zip direction. This view of the degradation mechanism was substantiated by the observation that several samples of highly irradiated PVF film aged in an oven at 105°C showed little visible change for over a week, but, as soon as they were sealed, became dramatically blackened and embrittled overnight.

Gamma Radiation Induced Conductivity in Glasses

By Dr. V. E. Culler, W. H. Barney, and H. E. Rexford, Corning Glass Works.

A study of the effects of gamma radiation on the electrical conductivity of glasses is of interest because of the practical uses of these insulators and because the mechanism of induced conductivity is not expected to be affected by chemical degradation caused by the irradiation (as in the case of organic insulation).

The first glass tested was a 0.09″ thick soda-lime-silicate (window) glass coated with air-drying silver paint. The room temperature resistivity of this glass was 10^{13} ohm-cm.

During irradiation (about 10^5 R/hr), a very slight change in the current value was noted. This change was in the negative direction; i.e., opposite to that of the battery current. At approximately 25°C and using a battery voltage of 22.5 volts, the current without radiation was 3.5×10^{-10} amperes. During irradiation, the current became 3.1×10^{-10} amperes, representing an apparent increase in the log resistivity from 12.71 to 12.76, using an area/thickness ratio of 20.2.

The effects of the irradiation on a borosilicate glass (also silver coated) were investigated to see if a similar effect would occur with a glass of higher resistivity. The battery current prior to irradiation was 2.8×10^{-12} amperes (22.5 volt battery) with a calculated log resistivity of 14.21. When the irradiation began, the direction of the current flow through the sample reversed, causing the electrometer to read negative. The current was -2.2×10^{-11} amperes with the 22.5 volt battery connected in the positive sense—a value approximately that found for the soda-lime-silicate glass. At zero battery voltage, the current was -3.4×10^{-11} amperes. Other currents were observed at different battery voltages and polarities.

The current values observed were plotted as a function of battery voltage and were found to lie on a straight line according to the equation $I = I_o + V/R$, where I is the observed current through the electrometer, I_o is the radiation induced current at zero battery voltage, V is the battery voltage, and R is the resistance of the sample. The dose rate was approximately 10^5 R/hr, and the calculated log resistivity was 13.97.

Three conclusions may be drawn from this study:

1) That gamma radiation has a negligible effect on the resistivity of the glasses measured.

2) That gamma radiation causes a current in the sample, the sample appearing as a current generator in the circuit.

3) That ordinary techniques may not be used to measure the effects of gamma radiation on the electrical conductivity of insulating materials, even in a system evacuated to 1 micron of mercury.

Theoretical Limitations on the Properties of Dielectric Liquids—Dielectric Constant and Electrical Loss

By Donald Tuomi, Thomas A. Edison Research Laboratory Div., McGraw-Edison Co.

At power line frequencies the electrical loss in a dielectric liquid is dominated by two mechanisms, namely: the intrinsic dipolar loss and the ionic conduction loss. The practical problem is to define, in a broad sense, how the molecular parameters of the system relate the dielectric constant to the electrical loss.

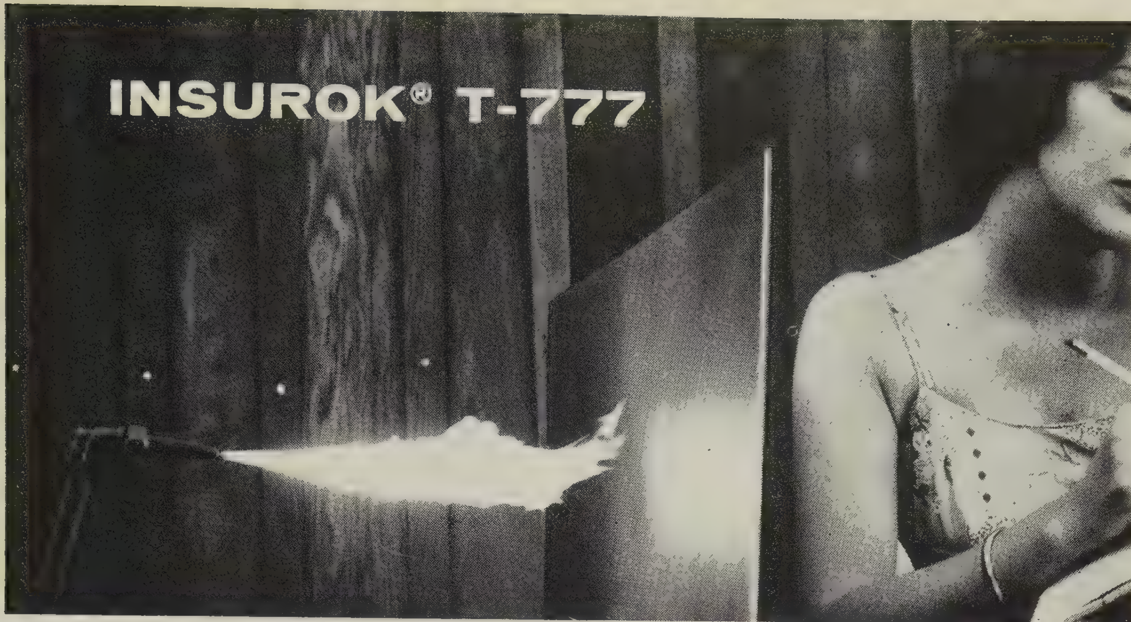
The Cole-Cole equivalent circuit model for a dielectric liquid describes the relationship between dielectric constant and electrical loss in terms of: 1) the zero frequency or static dielectric constant, ϵ_o; 2) the infinite or optical frequency dielectric constant, ϵ_{∞}; 3) the dipole relaxation time constant, τ_o; and 4) the dipole relaxation time distribution parameter, α.

For the purpose of survey calculations a value of 2.5 is postulated for ϵ_{∞}. Assuming that only one dipole relaxation process is involved, the relationship between the relative dielectric constant and the loss tangent is calculated as a function of τ_o and α. The results at 60 cps indicate that the loss tangent will be less than 0.1% for dielectric constants less than 100 if $\alpha < 0.6$ and $\tau_o < 10^{-9}$ sec. Since normal liquids have relaxation times of 10^{-10} to 10^{-11} seconds with α less than 0.3, the dipolar contribution to the electrical loss at power line frequencies will be negligible except for an extremely high viscosity or highly associated liquid.

The dielectric constant and loss tangent relationship is expressed in terms of the dielectric resistivity at 60 cps. In order to obtain a loss less than 0.1% at a dielectric constant of 100 or 1% at 10, the liquid resistivity must exceed 3×10^{11} ohm-cm. Granting that the dipolar loss is negligible, this loss must then be related to conduction by dissolved ions in the liquid.

For sufficiently dilute solutions the electrical conductance of a solution containing one chemical equivalent of ions does not vary over a factor of 10 with changes in the nature of the ion. Thus, postulating a value for the limiting equivalent conductance of A^+B^-, the ionic concentrations associated with a given loss can be calculated. For an ionic compound, A^+B^-, having a limiting equivalent conductance of 120 $ohm^{-1}\ cm^2$, the ion concentration limit at a 3×10^{11} ohm-cm resistivity is 2.8×10^{-11} chemical equivalents per liter or 3.4×10^{10} ions per cm^3. At 10^{13} ohm-cm the ion concentration decreases to 1×10^9 ions per cm^3 compared to 10^{22} atoms per cm^3. The ionic impurity limits in low electrical loss liquids fall below the limits frequently set for electronically active impurities in semiconductor materials.

The effective ion concentration depends



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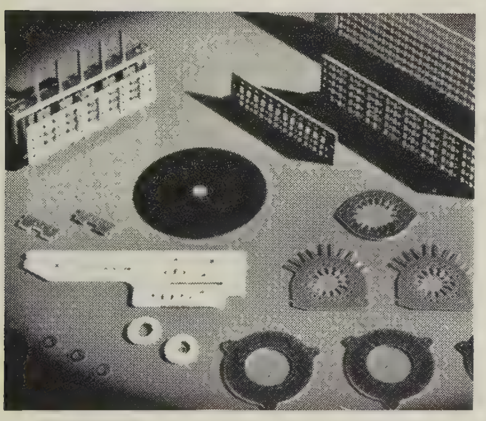

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on the extent to which ion pair association reduces the free ion concentration. The Bjerrum theory of ion pair formation relate the association constants for A^+,B ions to the dielectric constant, the ion charge, and to the temperature as a function of the molecular parameter "a" an internuclear distance for the ion pair. Thus, postulating reasonable values for "a" the total ionic concentration associated with a given free ion concentration can be calculated as a function of the dielectric constant.

In a practical sense the requirements for attaining a high dielectric constant with a low electrical loss at power line frequencies are a low absolute ionic concentration, less than parts per 10^{12}, and a fluidity corresponding to a normal liquid phase distribution of relaxation times.

Townsend Ionization Constants In n-Alkanes

By O. H. LeBlanc, Jr., and J. C. Devins, General Electrical Research Laboratory.

We recently measured the first Townsend ionization coefficient, α, in a series of n-alkyl chloride gases, and found that the dependence of α upon molecular structure in these gases was similar to, but different in detail from, that indirectly inferred in the hydrocarbon gases by Devins and Crowe and Heylen and Lewis from sparking potential measurements. In order to determine whether these differences are real or are the result of errors in analysis of the sparking potential data, we have undertaken the direct measurement of the first Townsend ionization coefficients in the n-alkane gases containing from one to six carbon atoms.

Crowe, Bragg, and Devins have, on theoretical grounds, related the ionization coefficient α to pressure p, field E, and to molecular structure through the relationships:

$$\alpha/p = A\ f(E/p)\, e^{-\frac{Bp}{E}}$$

$$B = k\theta\epsilon_i^{3/2}$$

A is a constant for a given gas, ϵ_i is the ionization potential, θ the Ramsauer cross section, and k, while not necessarily a constant for different gases, was found from sparking potential measurements to be so for the hydrocarbon gases. The pre-exponential factor f(E/p) was assumed to be equal to E/p for the hydrocarbons, although the range of E/p covered with the sparking potential measurements was insufficient to distinguish between f = E/p and f = 1. Our measurements for the alkyl chlorides showed that the equation gave a much better fit of these data if f = 1.

The gases were more than 99% pure. Pressures were varied from 0.5 to 20 mm Hg and electrode spacings from 0.2 to 3 cm.

We have plotted our experimentally determined ionization coefficients for the n-alkanes containing one to six carbon atoms. The abscissa was chosen to separate the individual curves; values of B were obtained from individual plots of log α/p against p/E. The curves all show linear regions over a variation in α/p of approximately 50-fold, with some curvature below Bp/E = 1 and above Bp/E = 5. Such deviations are to be expected according to the theory. Were f = E/p, the logarithm of α/p should be a linear function of p/E. The pronounced curvature suggests that for the alkanes, as for the alkyl chlorides, the equation better describes the results if f is chosen to be unity.

Values of B for the alkanes were recalculated from sparking potential data assuming f = 1 in the equation. The values are from 10 to 25% lower than those obtained in the present work.

An essential feature of the Townsend mechanism is the independence of the sparking potential on the level of cathode illumination, provided that adequate time is allowed for breakdown to occur. As Heylen and Lewis point out, however, for hydrocarbons, decreases in sparking potential of 10 to 20% are readily observable upon relatively moderate ultraviolet illumination of the cathode. Although with low levels of illumination they observed the same values of B for the alkanes as did Devins and Crowe; their values for the alkenes were distinctly lower.

Utilizing our measurements of α we can calculate from sparking potential measurements values for the second Townsend coefficient, τ, assuming the Townsend sparking criterion to be valid. For the relatively heavily illuminated gap, values of τ increase approximately exponentially with decreasing E/p, and lie in the range of 10^{-3} to 10^{-6}. With the lightly illuminated gaps of Heylen and Lewis and of Devins and Crowe, values of τ are more nearly independent of E/p and much lower (10^{-8} to 10^{-9}). These results are consistent with the hypothesis of Heylen and Lewis which suggests that if τ is very low for the hydrocarbons, appreciable space charge distortion of the field may occur below the Townsend threshold, even with moderate illumination.

Sparking potential measurements had indicated that the cross section θ was a colligative function of the number and types of atoms in a molecule if the contribution of the singly bonded carbon atoms is zero. We plot $B/\epsilon_i^{3/2}$, obtained from our direct α measurements for the n-alkanes and n-alkyl chlorides, versus the number of hydrogen atoms. A 12% difference in slope suggests either a slightly different hydrogen atom contribution or different values of k for the n-alkane and n-alkyl chloride series.

The constant A for the n-alkane gases appears to be proportional to the number of hydrogen atoms per molecule. An understanding of the dependence of A upon molecular structure must await further theoretical work.

The Reactions of Active Nitrogen With Polyolefins

By J. L. Weininger, Research Laboratory, General Electric Co.

Active nitrogen is the product of an electric discharge in nitrogen. It is characterized by a prolonged yellow afterglow and strong chemical reactivity.

Our interest in the behavior of insulating materials exposed to corona, together with that in surface reactions, led to the investigation of polyethylene. "Marlex"-50 was chosen as a polymer because it has a simple structure and well-defined properties. It was exposed to active nitrogen at temperatures from 39°C to 141°C. Two other polyolefins—polyisopropylene and polyisobutylene—were also investigated for a comparison of their behavior with that of polyethylene.

The results of this study are:

a) The quantitative determination of condensable products of the reaction (approximately 80% hydrogen cyanide and 20% cyanogen).

b) The observation of cross-linking of the polymer and a decrease in its vinyl concentration.

c) The estimation of activation energies of these processes.

There is a parallelism between active nitrogen and mild radiation-induced reactions. Together with the above results this makes it possible to postulate the following mechanism for the reaction of active nitrogen with polyethylene. In the primary process a nitrogen atom attacks a carbon-carbon bond and forms one of three reaction complexes.

This leads to splitting-off of either HCN or CN and H atoms. One of the complexes may form new vinyl bonds (chain-unzipping); all three complexes may lead to chain-terminating free radicals, resulting from chain-scission. The evolved H atoms will abstract other H atoms from intact chains to yield free radicals suitable for crosslinking. This may take place by crosslinking of neighboring polymer chains, or by end-linking.

It is also postulated, subject to further experimental verification, that active nitrogen, or atomic H liberated by it, can diffuse into the non-crystalline part of the polymer and can react below the surface. This is consistent with the observation of crosslinking in depth, and with the magnitudes of the observed activation energies.

There is a fairly abrupt increase in the reactivity of polyethylene (towards active nitrogen) at its crystal melting point (136°C for Marlex-50). Polypropylene is more reactive than the comparable linear polyethylene. Similarly to polyethylene, polypropylene crosslinks and produces relatively more nitrogen-containing products, including ammonia. Polyisobutylene does not crosslink but forms ammonia as one of the main products of the reaction with active nitrogen.

The Hygroexpansivity of Cellulose Papers

By Thomas D. Callinan, Joseph S. Crimi, Paul Schwartz, and Louis H. Wirtz, International Business Machines Corp.

Cellulose papers expand and contract when the humidity of the atmosphere with which they are in equilibrium changes. This phenomenon—known as hygroexpansivity—plays a significant role in the manufacture of such electrical components as capacitors, cables, and transformers, since the units may suffer from shrinkage and consequent mechanical instability on being dried before impregnation. While many investigations have been made of the phenomenon, most of the work has been hampered and made useless by the failure of the researchers to establish repeatable data. It was the purpose of this work to

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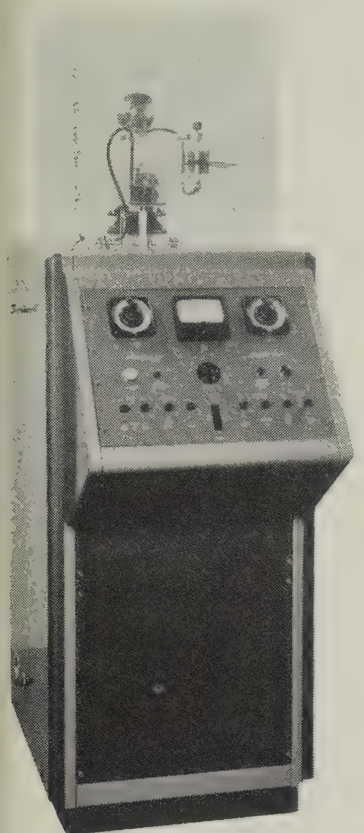

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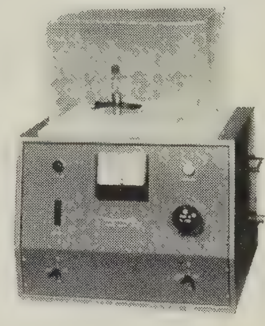

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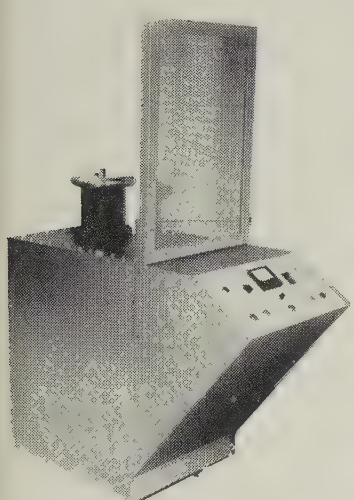

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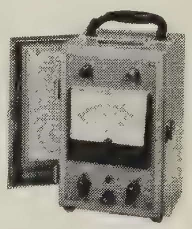

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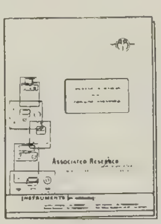

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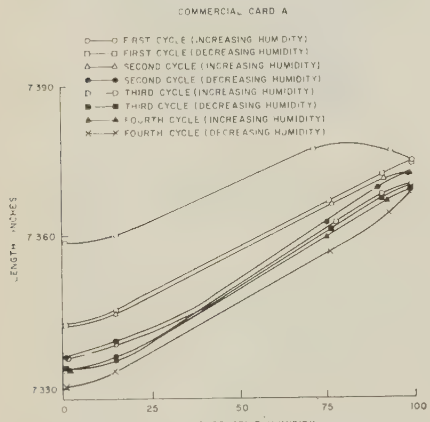
determine why the effect was not reproducible within close limits and, from the results, to understand the mechanism of hygroexpansivity.

Papers made from kraft pulp, semi-bleached sulfate pulp, and bleached sulfite pulp were studied. In establishing the hygroexpansivity coefficients of the papers, the samples were subjected to humidity cycles between 0 and 98% RH.

Typical of the results obtained are those shown for a kraft paper in the figure. It can be seen that on being subjected to increasing humidity the paper expands until it equilibrates at 75% RH, after which it shrinks as the humidity is raised to 98% RH. On being dried the paper decreases in length permanently. Subjecting the sample



to more humidity cyclings results in even more permanent shrinkage. Four cycles were required before reproducibility was obtained.

Studies on five commercial cellulose papers established that all were originally in various states of strain between 0.06 and 0.1%. These strains developed in the papers during their manufacture. The strains were removed when the papers were subjected to high relative humidities (98%) for prolonged periods (48 hours) and dried slowly without tension. After de-straining, the papers possessed reproducible hygroexpansivity coefficients and showed little, if any, hysteresis. On the other hand, the magnitude of the hygroexpansivity coefficients was almost twice as great in a de-strained or relaxed paper as in a strained or unrelaxed one.

By studying simultaneously the expansion which the paper underwent on being subjected to increasing humidity and the shrinkage it underwent while maintained at a high humidity for prolonged periods, it is possible to understand the nature of this graph.

From this study it appears that the failure of earlier investigators to establish duplicable results in their studies arose because they were using strained papers, the hygroexpansivities of which are dependent upon the dynamics of their manufacture and their history.

The Electrical Properties Of Some Solid Organic Esters

By Ann M. Parks, International Business Machines Corp.

In order to determine the effect of the length of the hydrocarbon portion and separation of the dipoles on the physical and electrical properties of symmetrical diesters of dibasic acids, a series of these esters has been prepared in a highly purified form. Three normal long-chained alcohols (dodecyl, octadecyl, and docosyl), as well ethyl alcohol, were reacted in turn with a series of dibasic acids (sebacic, pimelic, adipic, and glutaric) to form diesters.

With the exception of the ethyl esters, these esters are all white, waxy solids and the data show that a systematic increase in both melting points and refractive indices occurs with increasing molecular weight or length of the alcohol portion of the molecule within any one acid series. In each series there is less of a change in the physical properties when the alcohol portion is increased from 18 to 22 than when it is decreased to 12.

It should be further noted that whereas the length of the alcohol portion greatly affects the physical properties, the separation of the carbonyl groups has much less of an effect. Thus with any one alcohol the physical properties of the esters resulting from reaction with a dibasic acid do not vary greatly, especially with the longer chained alcohols.

The esters are all polar, crystalline materials, and plots of dielectric constant as a function of temperature show a gradual rise as the temperature is increased to the melting point. A sharp rise occurs at this point, and is followed by a gradual decrease in the liquid. The dielectric loss factors may or may not exhibit maxima at characteristic temperatures below the melting points for each frequency. The presence of these maxima is indicative of molecular motion in the solid state and depends on the manner in which the esters crystallize. This behavior is predictable from consideration of the zig zag structure of the dibasic acids themselves, and dipole moment measurements in benzene solution allow the most probable structures to be determined.

As has been seen in the physical properties, a systematic change in the dielectric properties also occurs by changing the molecular structure of these esters. The data presented may be extended to include other esters of a similar type.

Electrical Surface Failure in the Presence of Conducting Liquid Contaminant

By K. N. Mathes and E. J. McGowan, General Engineering Laboratory, General Electric Co.

When electrical failure of the surface of an insulation occurs progressively in the presence of contamination, the resulting breakdown is called "tracking." Many tracking tests have been devised but they have been limited by poor reproducibility, restricted scope, or inability to represent service conditions adequately. Test methods suitable for the best track-resistant materials have required hundreds or even thousand of hours to reach a definitive end point.

An inclined-plane, liquid contaminant tracking test has been developed in which the test variables can be precisely controlled and varied as necessary over a wide range. By the proper choice of the test parameters, a wide variety of service conditions apparently can be represented and different types of tracking and scintillation erosion can be produced.

The principal factors controlling the severity of the surface scintillation and hence the tendency to initiate tracking are:

1) Sample and electrode geometry.
2) Contaminant conductivity.
3) Rate at which contaminant is applied to the surface.
4) Voltage stress.
5) Ability of the contaminant to "wet" the surface.

Critical interrelationships exist. For example, with each given conductivity and rate of contaminant application, scintillation can occur over only a limited range of voltage stress.

The chemical nature of the contaminant appears to be of secondary importance in initiating tracking but is of primary importance in determining the rate of erosion. Unfortunately, previous tests generally have not emphasized the importance of erosion—which may be as important a limitation in some applications as tracking. The parameters of the inclined-plane, liquid contaminant test can be selected to emphasize failure by erosion.

A 0.1% aqueous solution of ammonium chloride has been selected as the contaminant for much of the experimental tracking program. By increasing the voltage in steps, a test end point called the "initial tracking voltage" can be obtained for various materials.

The values of initial tracking voltage provide, as does the IEC test, a comparative tracking index for materials with an extremely wide range of tracking resistance. Ultimately it may be theoretically possible to correlate such test values with service conditions if these conditions can be adequately defined. It is certain that field conditions leading to tracking are actually extremely complex and variable.

Field observations have indicated that the critical conditions leading to the electrical scintillations responsible for tracking and erosion seem to occur only for very short periods at more or less widely spaced intervals of time. Consequently, by continuously producing controlled scintillation, it is possible to greatly accelerate tracking degradation with the inclined-plane test as compared to the relatively slow and erratic progress of tracking under field conditions.

Residual Losses in a Guard-Ring Micrometer-Electrode Holder For Solid-Disk Dielectric Specimens

By Arnold H. Scott and William P. Harris, National Bureau of Standards, U. S. Department of Commerce.

Residual losses occurring in the specimen holder and in the bridge standard capacitor must be taken into account in order to make accurate bridge measurements of the dielectric losses of materials that have very low losses. Also, knowledge of the exact spacing of the electrodes is required for accurate determination of the dielectric constant of materials. To better meet these requirements, a new specimen holder has been designed and constructed (figure 1).

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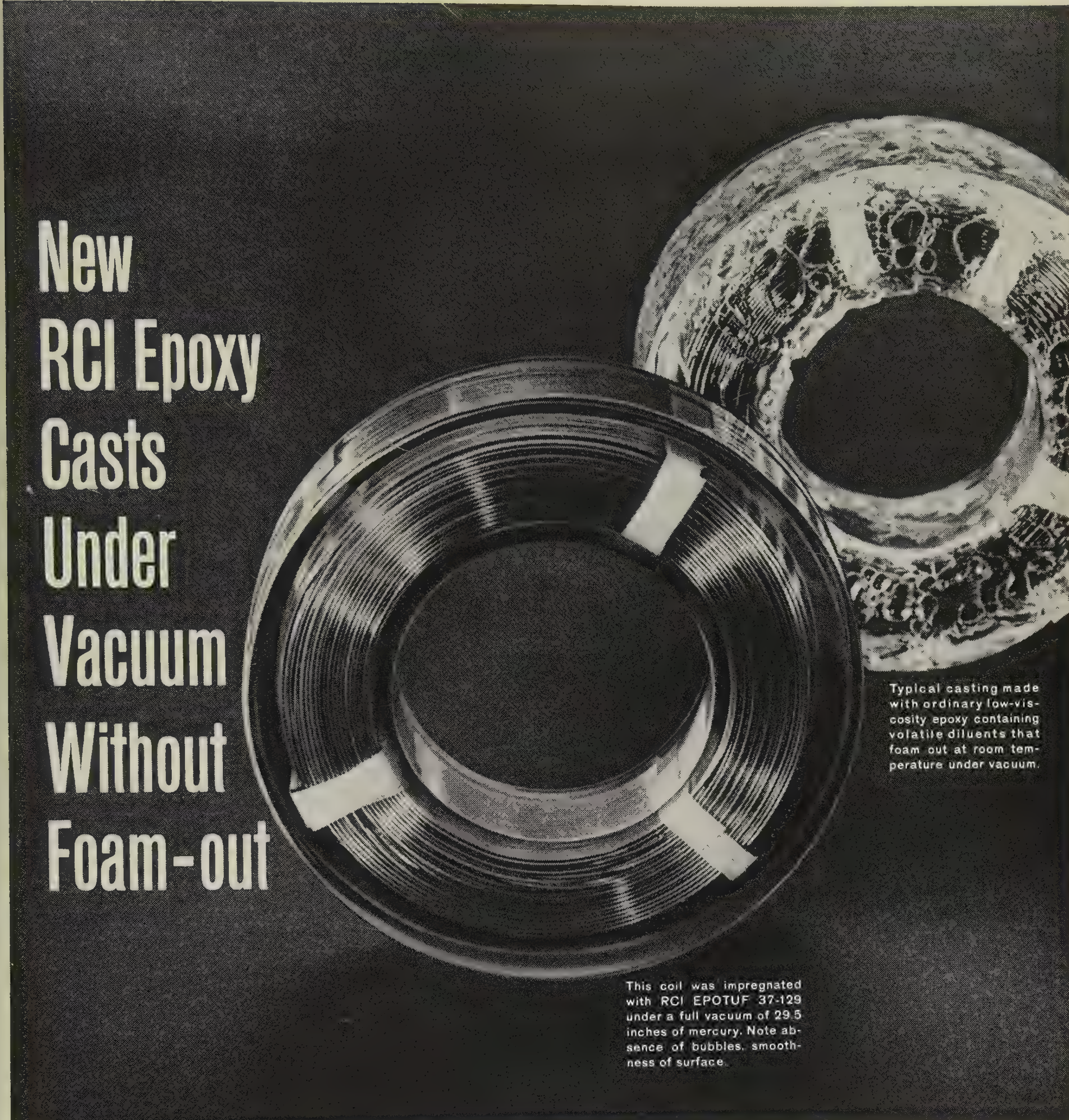

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gages, the electrodes of the holder can be adjusted to be parallel to about one micron, and the zero correction of the micrometer can be determined to ±1 micron. Using a modification of a technique used by Astin and others, the residual loss angles of the holder and its connecting leads and of the bridge standard capacitor were determined to ±1 or 2 microradians.

The residual losses in the holder and in the bridge standard variable air capacitor were investigated using the substitution method with a low-voltage Schering bridge. A series of measurements of the apparent loss angle of the specimen holder can be used to determine the true loss angles of the specimen holder and of the bridge standard capacitor.

One of the main objectives of the present work was the determination of the losses arising from the presence of a surface film on the electrodes, such as an oxide layer, in order to correct for errors due to such losses in loss measurements made on dielectric materials.

Losses in a capacitor can be represented at a single frequency as a resistance in series with the capacitance, and the loss angle, δ, is related to this resistance by $\tan \delta = D = \omega RC$, where

δ = loss angle of the capacitor
D = dissipation factor of the capacitor
C = capacitance of the capacitor
R = equivalent series resistance of the capacitor.

Of course for very small loss angles, such as those encountered here, $\tan \delta$ is almost exactly the same as δ, the loss angle.

If the distribution of a lossy surface layer is assumed to be reasonably uniform, then the conductance per unit area would be constant. The bridge standard capacitor is constructed with electrodes of fixed spacing, and the capacitance is varied by changing the active electrode area by moving interleaving plates. Therefore, this capacitor has a component of loss angle that is constant as the capacitance is varied, for both the capacitance and the conductance due to a lossy surface film are proportional to the electrode area. Thus the product RC is constant, yielding a constant component of loss angle.

The specimen holder, on the contrary, has electrodes of fixed area, and the capacitance can be varied by changing the electrode separation. Since the equivalent series resistance due to the lossy surface layer can be assumed to be reasonably constant, the loss angle of the empty specimen holder will be proportional to the capacitance.

A series of measurements of the apparent loss angle of the empty specimen holder was made, varying the capacitance of the specimen holder by changing the separation of the electrodes. When the results of these loss measurements are plotted against the capacitance of the holder, a straight-line plot with negative intercept and positive slope is obtained. This arises from the fact that the apparent loss angle of the specimen holder is always the true loss angle of the holder minus the true loss angle of the bridge standard capacitor. The intercept is a measure of the losses in the bridge standard capacitor; the slope is a measure of the losses in the specimen holder.

Because the work on the measurement of loss angles of low-loss materials was to be performed under several conditions of ambient relative humidity (RH), it was necessary to determine the residual losses of the specimen holder as a function of RH. Only the ambient RH of the holder was varied; the RH surrounding the bridge standard capacitor was maintained as low as was practicable by passing a stream of dried nitrogen through the enclosure containing it. Therefore, the loss angle of the bridge standard capacitor should remain relatively unchanged, even though the loss angle of the holder might change as the RH surrounding it was varied.

Results of measurements made at 100 cps, 1 kc, 10 kc, and 100 kc, with the holder in a very dry (RH less than 1.5%) atmosphere are plotted. Similar measurements made with the RH surrounding the holder at 52% are also plotted.

Examination of these two plots reveals several points of interest. First, it is evident that the intercepts, corresponding to the values of the dissipation factor of the bridge standard capacitor, are nearly the same for the two sets of measurements, as expected. Another striking fact is that the values of dissipation factor are all

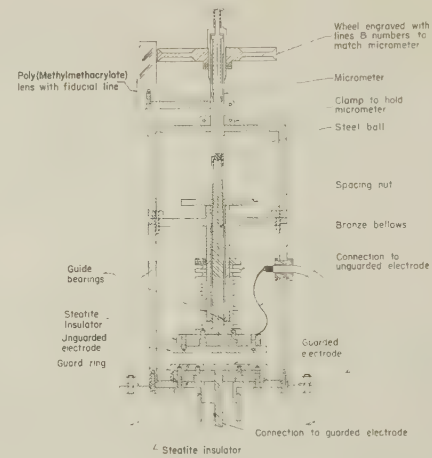


Figure 1, schematic diagram of the guard-ring micrometer-electrode holder for solid-disk dielectric specimens.

rather small. Therefore, the errors introduced by neglecting to take residual losses into account are very small, except for materials with very small loss angles. Raising the RH of the atmosphere surrounding the specimen holder increases the loss angle observed. This effect is more pronounced at the lower frequencies studied, giving some indication that there is a dispersion region occurring at low frequency. Looking again at the intercepts, we see that the loss angle of the bridge standard capacitor is also greater at lower frequency.

Now that the loss angle of the bridge standard capacitor has been evaluated, it is a simple matter to use this measured value as a correction to measurements of loss angle made with this capacitor; the value of the loss angle of the bridge standard capacitor must always be added to the observed value. Correcting for the effect of the residual losses in the specimen holder is not quite so simple. However, armed with the knowledge of the loss angle of the empty specimen holder, one can make what appear to be reasonable assumptions and determine a correction to apply, secur in the knowledge that the error is smal in any event.

Influences of Metallic Fillers On Properties of Epoxy Plastics

By John Delmonte, Furane Plastics Inc.

Wide toleration of metallic fillers is in dicated by liquid epoxy resins. Filler ad ditions are usually motivated by considera ations of enhanced physical and electrica qualities. The changes which occur are no always predictable.

The metallic fillers used most abundantl in the experiments were a finely divide aluminum powder and fine aluminum needle-like particles about ⅛" long an randomly distributed during the mixing operation. Other metallic particles wer also investigated.

Results reveal several informative trends

Density: The percentage increase in den sity parallels the percent volume occupie by the aluminum particles. It is probabl that as the proportion of metallic filler is increased and as the mixture become less pourable, the amount of entrapped ai will increase—yielding less significant ap parent density readings.

Thermal Conductivity: The data on hea transfer demonstrate about a three-fold in crease in thermal conductivity when the volume of aluminum in the mixture is ap proximately 30%. Unexpected was the be havior of the larger acicular form of alumi num, which in the proportions used, indi cates not as much improvement in therma conductivity as for the finely divdec powder.

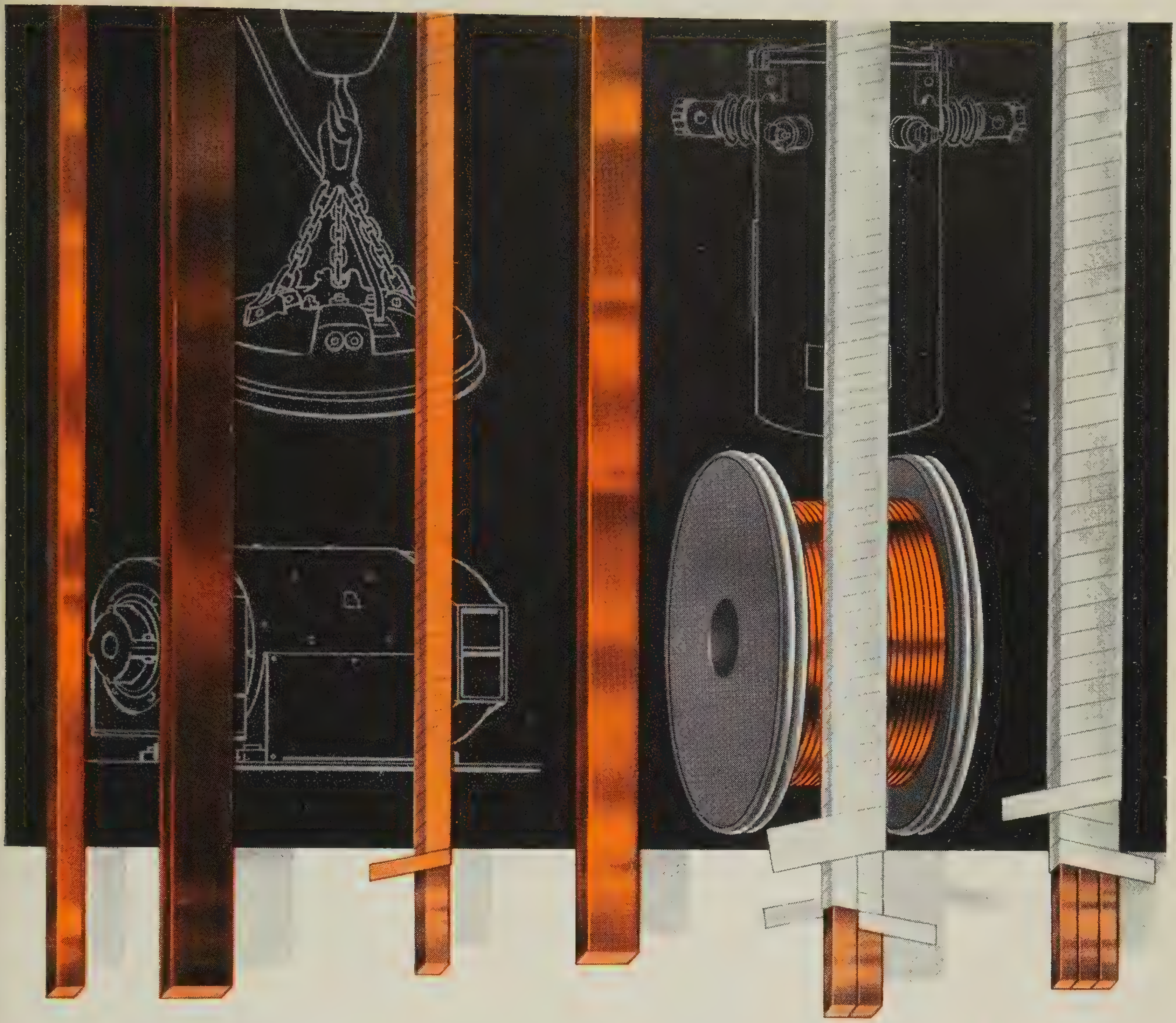
Volume Resistivity: It is noteworthy that volume resistivity changes favored the larger size aluminum particles which dem onstrated 10 times greater conductivity with 17.7% aluminum volume as compared with a minor improvement in conductivity with the smaller aluminum particles at the same volume loading.

Physical Properties: Within the propor tions of aluminum filler and epoxy tested, compressive strength values and flexural strength values showed little variation and no significant trend. However, most sig nificant was the modulus of elasticity which increased decidedly—particularly with the smaller aluminum particle additions.

Dielectric Loss Factor and Dielectric Constant: Measured at 1 kc, the trends in loss factor were indecisive, though dielec tric constant depicted the decided increase expected on the addition of aluminum powder. The same observations were made when D (dissipation factor) and K were evaluated at elevated temperatures as well as at lower temperature.

Mixtures of various commercial metallic fillers were made with liquid epoxy resin to a viscosity (Brookfield) of the order of 2 to 3 × 10^6 centipoise at 75°F. Results point to the surprising fact that with high metallic filler concentration thermal conductivity is improved about five-fold when compounding and cure are performed at atmospheric pressure. Under externally applied pressure and metal filler and fiber distribution, thermal conductivity is reported as substantially better. On the other hand, volume resistivity is influenced by

Continued on page 108



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metallic fillers and their surface conditions much more significantly than thermal conductivity is influenced. Unexpected was the lack of correlation between changes in thermal conductivity and electrical conductivity. It may be presumed that the oxidized surfaces on the filler particles are a more serious deterrent to electrical conductivity than to thermal conductivity.

Dielectric Properties of Glasses

By Chikara Hirayama and Daniel Berg, Westinghouse Electric Corp.

The d-c resistivity of inorganic glasses is characterized over a large temperature range by the equation (Rasch-Hinrichsen Law):

$$\rho = \rho_o \epsilon^{E/kT}$$

where ρ is the resistivity, ρ_o a pre-exponential constant, E an activation energy, k is Boltzmann's constant, and T the absolute temperature.

This paper reported the electrical properties of five glasses of varying sodium and potassium content as shown in table 1.

Table 1—Glass Composition, in Weight Percent of Sodium and Potassium Oxide

Glass	Na_2O	K_2O
Window	14.2	—
Pyrex	3.8	0.4
Vycor	< 0.02	< 0.02
G	—	
H	—	–

Table 2—Energy of Activation and Pre-Exponential Term for the Conductivity of the Glasses

Glass	E, kcal/mole	log ρ_o
Window	17.4	−0.2
Pyrex	20.6	−0.45
Vycor	24.4	−0.5
G	39.2	−3.3
H	39.2	−3.8

Typical results at 100 cps are shown in figure 1. In figure 2, the resistivity-temperature relationship is shown for the glasses. The energies of activation, E, in kcal/mole, calculated from the curves in figure 2, are shown in table 2 along with the pre-exponential factor log ρ_o.

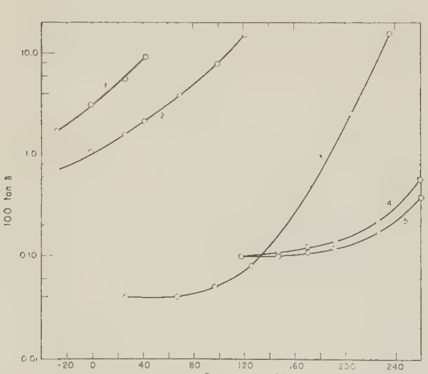


Figure 1, dissipation factor at 100 cycles as a function of temperature: 1) window glass, 2) "Pyrex," 3) "Vycor," 4) glass H, 5) glass G.

The effect of sodium on the electrical properties of the glasses is clearly indicated in the resistivities and dissipation factors shown in figures 1 and 2. The higher the sodium content, the higher the conductivity at any temperature. Also, the higher sodium content glasses have a lower activation energy, E. The rapid increase of the tan δ with temperature occurs

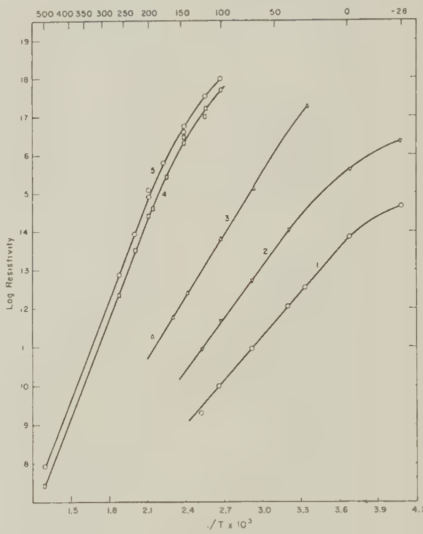


Figure 2, resistivity-temperature relationship of 1) window glass, 2) "Pyrex," 3) "Vycor," 4) glass H, and 5) glass G.

at lower temperatures for the higher sodium content glasses.

One interesting feature shown in figure 2 is the decided deviation from the simple

$$\rho = \rho_o \epsilon^{E/kT}$$

expression for some of the glasses at *low* temperatures. This type of behavior has been noted for crystalline ionic conductors and the deviation at low temperatures (extrinsic conductivity) has been attributed to the movement of vacancies in the lattice. conduction along grain boundaries, and frozen-in defects. Impurity and grain boundary conduction in glass is precluded on the basis of its liquid structure.

The Gassing Properties Of Aromatic Hydrocarbons

By Walter F. Olds and George Feick, Arthur D. Little, Inc.; and Edward D. Eich, Anaconda Wire and Cable Co.

This paper reported some results obtained in the measurement of the gassing coefficients of a number of pure aromatic and alkyl aromatic hydrocarbons. A negative value of the gas coefficient denotes absorption of gas by the oil.

A table showed the gas coefficients, measured at 85°C, of a number of aromatic and substituted aromatic hydrocarbons arranged in order of decreasing boiling point. It appears that as the vapor pressure increases to about 1 mm Hg, the gas coefficients tend to reach optimum values of around −100 to −110. At higher values of vapor pressure, the gas coefficients decrease to zero, probably because of decreasing hydrogen concentration and of the tendency of the aromatic vapor to quench the glow discharge. The same facts are shown graphically in figure 1, in which the

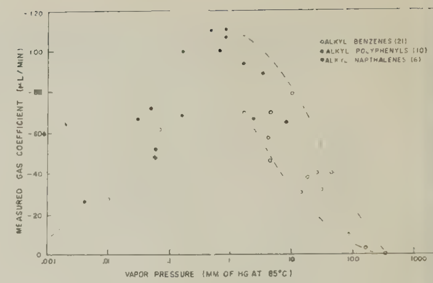


Figure 1, measured gassing coefficients of various aromatic hydrocarbons at 85°C.

gas coefficient of each compound is plotted against the logarithm of its vapor pressure. There are two probable reasons for the scatter of the points in this figure—first, there is a wide variation in the percentage of aromatic carbon in these compounds and second, the various aromatic ring systems (benzene, naphthalene, diphenyl, etc.) may differ in their reactivity toward activated hydrogen.

The effect of varying aromaticity may be compensated by defining a reduced gas coefficient as the measured coefficient divided by the fraction of aromatic carbon in the hydrocarbon molecule. This in effect reduces the gas coefficient to a 100% aromatic basis by ignoring the aliphatic part of the molecule. This procedure is open to the objection that the aliphatic parts of the molecule may actually evolve gas in this test. More information on the behavior of aliphatic hydrocarbons is needed, however, before this question can be dealt with satisfactorily.

The reduced gassing coefficients for the test series of hydrocarbons are plotted against the logarithm of the vapor pressure in figure 2. This figure shows that not only has much of the scatter been eliminated but also that the points tend to fall on three separate curves according to chemical structure. The benzene derivatives give the highest values of reduced gas coefficient at a given vapor pressure, the naphthalene derivatives give lower values, and the poly-

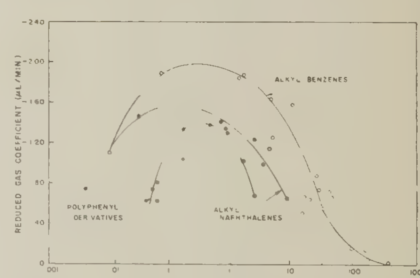
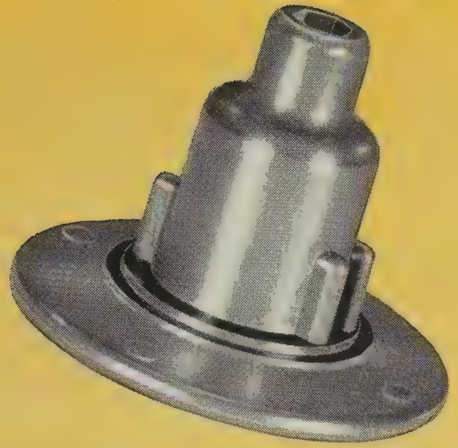


Figure 2, reduced gassing coefficients of various aromatic hydrocarbons at 85°C.

phenyl derivatives give the lowest values. The remaining scatter among the benzene derivatives may be due to variations in steric hindrance and other factors not accounted for in the above analysis.

In general, we may expect that variations in gassing coefficient with temperature may be due both to changes in reaction rate and to changes in hydrocarbon concentration in the vapor phase due to varying vapor pressure of the oil. Our data on the variation of gassing coefficient with vapor pressure alone permit a separation of these two temperature effects.

Figure 3 shows the variation of gassing



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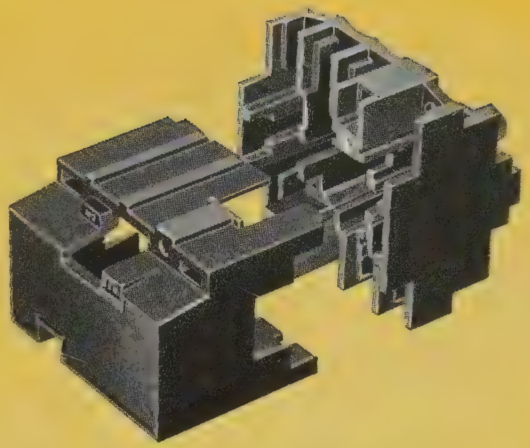

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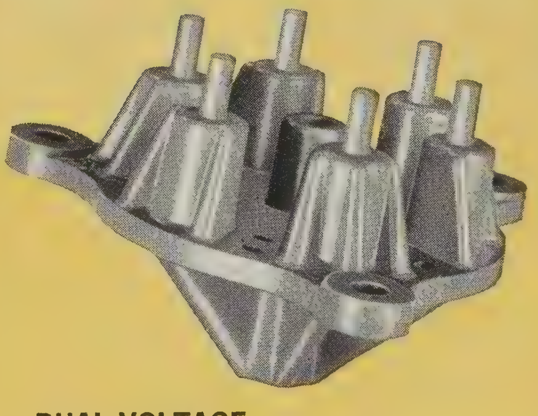

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coefficient for tertiary butyl benzene as its vapor pressure is varied from about 0.002 mm Hg to 110 mm Hg by changing the test temperature from −50° to +115°C. Comparison of figure 3 with figure 1 shows a striking similarity of form. Not only does the gassing coefficient in the two curves approach zero at about the same values of vapor pressure, but the maximum occurs near a pressure of 1 mm Hg in both cases.

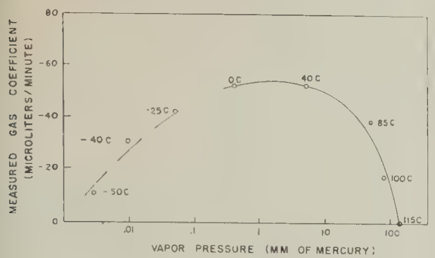


Figure 3, gassing coefficients of tertiary butyl benzene.

It appears that the main effect of temperature on the gassing coefficients of aromatic hydrocarbons is due to change of vapor pressure rather than to variation of reaction rate. This leads to the conclusion that the activation energy for the hydrogenation reaction is derived almost entirely from the electric field rather than from thermal sources.

Some Novel Resonant Cavity Techniques for the Evaluation Of Artificial Dielectrics

By D. Edelson, W. A. Yager, and W. McMahon, Bell Telephone Laboratories, Inc.

Techniques have been devised using partially filled TE-101 rectangular cavities for the measurement of electrical properties of metal-loaded polystyrene foam dielectrics. By combining measurements made with the sample in various positions in the cavities, the dielectric constant and its uniformity and isotropy, as well as the electric and magnetic dissipation factor, are obtained. Cavities for laboratory investigation and for production testing are described.

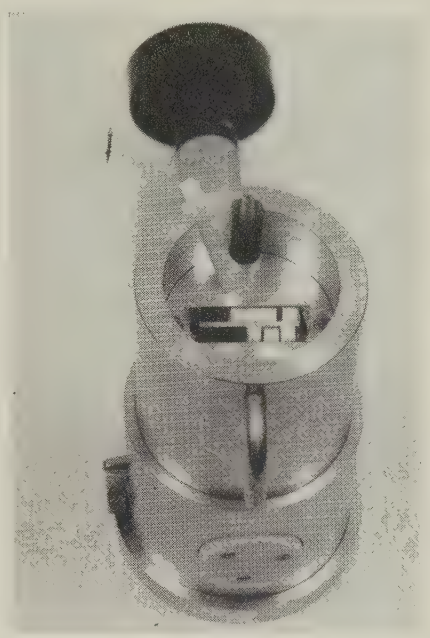
A Liquid Displacement Test Method For Determining the Anisotropic Dielectric Properties of Printed Wiring Boards

By Kenneth G. Coutlee, Bell Telephone Laboratories, Inc.

The increasing use of printed wiring circuits at very high and microwave frequencies has created a growing need for insulating materials having isotropic dielectric constant and dissipation factor in both the parallel and perpendicular direction. It is also important that these properties be relatively unaffected by absorbed moisture.

A test method has been developed using a small high frequency liquid displacement test cell employing a stack of ⅛″ x ⅛″ x 1⅛″ test specimens immersed in a suitable liquid dielectric between the electrodes of the cell with the specimens oriented in either the perpendicular or parallel direction.

Tests made on experimental and commercially available sheet insulating material show wide differences in the K and DF in the two directions after drying 24 hours at 50°C and particularly after immersion in water for 24 hours, over a fre-



quency range of 1 kc to 61 mc. The glass-filled laminates exhibit the greatest anisotropy with mineral-filled polyethylene somewhat less and with practically no directional differences for high density polyethylene, "Teflon," and polypropylene.

An Ultra Low Frequency Bridge For Dielectric Measurements

By Donald J. Scheiber, National Bureau of Standards.

In 1955 I. R. Weingarten presented a paper in which he described a bridge capable of measuring dielectric properties down to the very low frequency of 0.01 cps. The present paper summarizes the effort made in the Dielectrics Section of the National Bureau of Standards to improve and test this apparatus to the point that it can be used to make precise measurements of dielectric properties at these low frequencies. The present bridge operates at frequencies between 0.01 and 200 cps, measuring capacitances up to 100 pf and conductances between 10^{-9} to 10^{-15} mhos. It is possible to expand these measurable ranges.

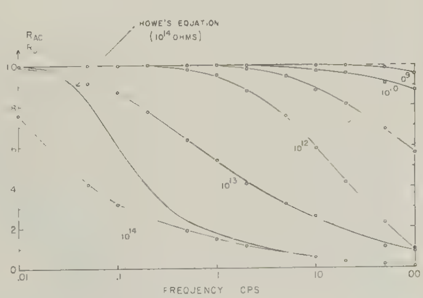


Figure 1, resistance of six resistors as a function of frequency.

Thirty substitution measurements on a 5.004 pf fixed reference standard capacitor averaged to 5.0055 pf with a standard devi-

ation of 0.0013 pf. These measurements were made at frequencies between 200 and 0.1 cps, while the capacitor was in parallel with resistors ranging in value between 10^{10} to 10^{14} ohms.

Resistors were measured in a chamber through which a flow of dry N_2 was maintained. The commercial resistors measured consisted of a resistive element

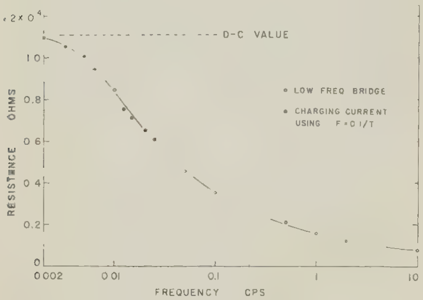


Figure 2, frequency dependence for a nominal 10^{14} ohm resistor.

sealed inside a glass envelope. The low frequency values and the independently determined d-c values agreed to within one percent for all except the 10^{14} ohm resistor. At high frequencies there is in general drastic departure from the d-c value for nearly all the resistors. This result was corroborated by measurements using a Schering bridge near 100 cps. It must be concluded therefore that these resistors are frequency dependent.

This frequency dependence is understandable in light of the theoretical work of Howe. He considered a cylindrical composition resistor and associated with it a certain capacitance per unit length. He showed that the parallel resistance and capacitance drop sharply from their d-c values when the frequency is increased above a certain value. From his work, it can be inferred that when the product of the frequency and of the d-c resistance is near 10^{12} cps ohms, these resistors should begin to exhibit a frequency dependence. Referring to figure 1 it can be seen that these predictions are roughly verified.

The nominal 10^{14} ohm resistor was further investigated using d-c techniques. Its resistance was determined as a function of the time, t, after applying 20 volts d-c

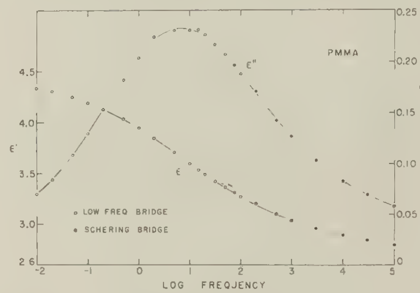


Figure 3, dielectric constant, ϵ', and loss index, ϵ'', of a specimen of PMMA at 23.7°C.

across it. A frequency was associated with the time, t, according to an approximate equation due to Hamon:

$$f=0.1/t.$$

The results of this experiment, shown in figure 2, agree quite acceptably with the low frequency a-c measurements.

These measurements of "known" conductances adequately demonstrate the ability of the bridge to accurately measure conductances between 10^{-9} and 10^{-14} mhos at very low frequencies.

The bridge's accuracy at high frequencies is demonstrable by measuring the dielectric properties of a specimen and comparing the results with those obtained using a conventional Schering bridge.

One of the materials measured was polymethylmethacrylate (PMMA). The results are shown in figure 3. The agreement between the two instruments is indicated by the smooth curves obtained.

Fused silica, which has a low loss index, was also measured. The results are shown in figure 4. There is a visible discontinuity in the ϵ' data, but the error is only 0.5%. The ϵ'' data from the low frequency bridge

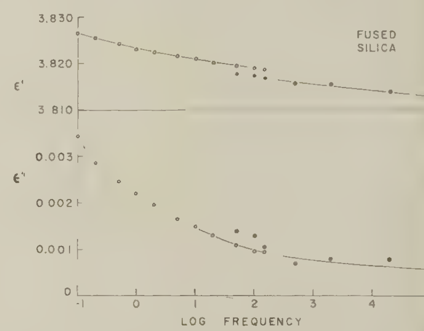
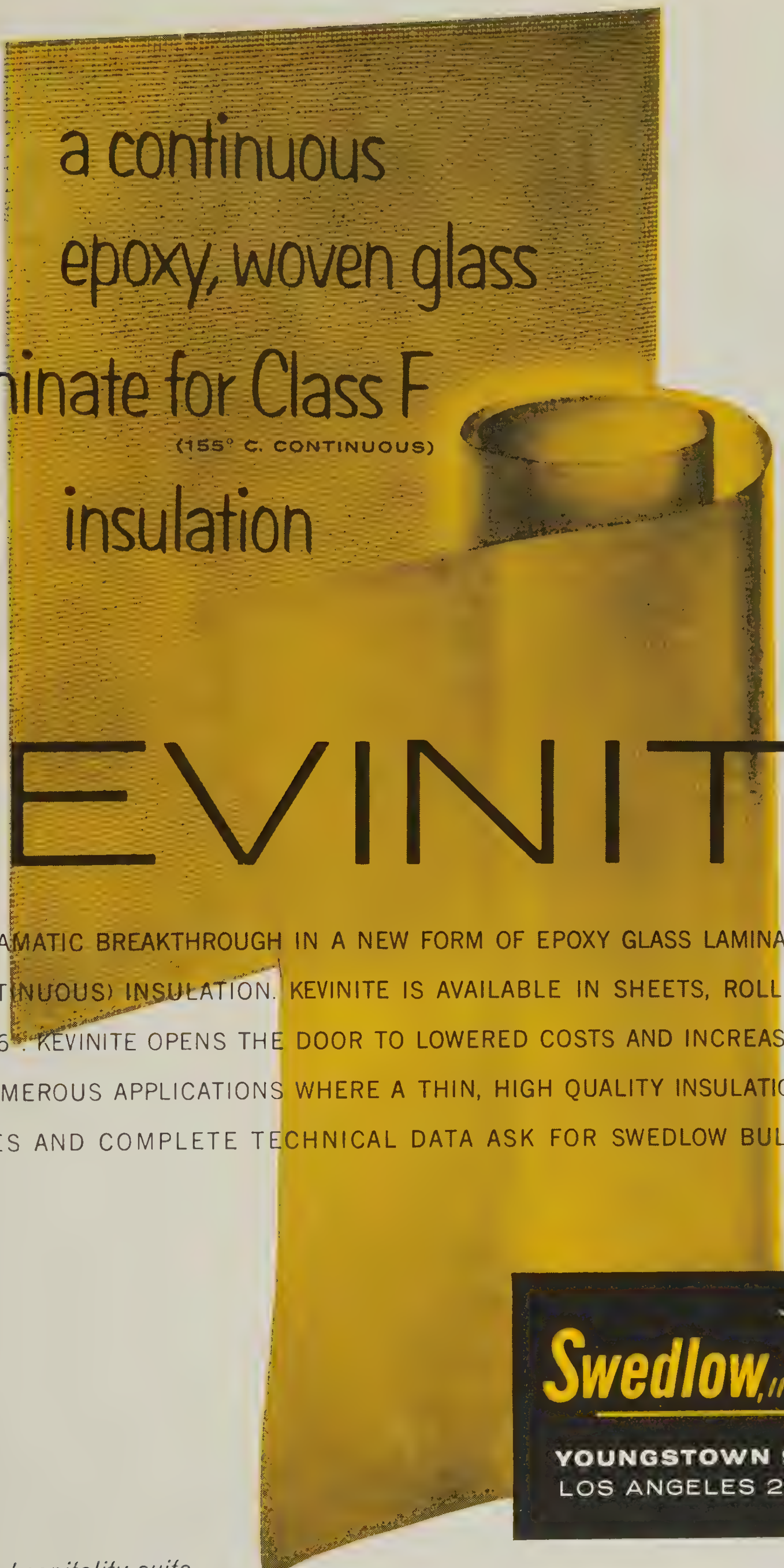


Figure 4, dielectric constant, ϵ', and loss index, ϵ'', of a specimen of fused silica at 24.2°C.



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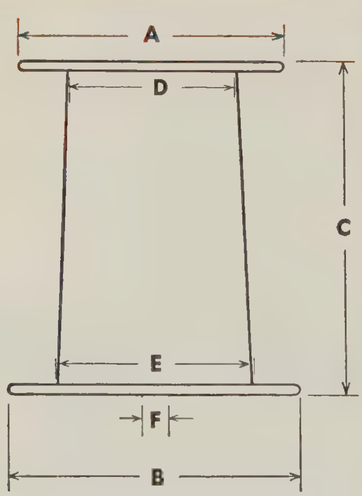

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ALUMINUM	37	16
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PHOSPHOR BRONZE	120	50
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form a smooth curve which, near 100 cps, easily joins with the somewhat scattered Schering bridge data.

Studies on the Thermal Degradation Elevator Effect

By Roy R. Divis, Amphenol-Borg Electronics Corp.

In a previous paper it was reported that a sudden increase in the rate of weight loss of polychlorotrifluoroethylene (CTFE) was observed after heating had been conducted for a period of time. As shown in figure 1, the phenomenon was observed to occur between 840 and 1000 hours of heating at 235°C. A corresponding increase in the rate of molecular weight degradation

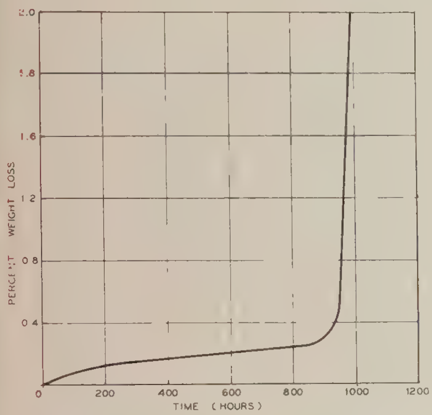


Figure 1, weight loss vs. time at 235°C for polychlorotrifluoroethylene (CTFE).

was also apparent. Figure 2 illustrates the effect when zero-strength-time, known as the ZST test, is used as a measure of molecular weight. The same effect, as shown in figure 3, is observed if flow index is used to determine average molecular weight. In all cases, the commonly observed relationship of weight loss or molecular weight with time is interrupted by a sudden rate surge. The designation of "elevator effect" is used when referring to this phenomenon.

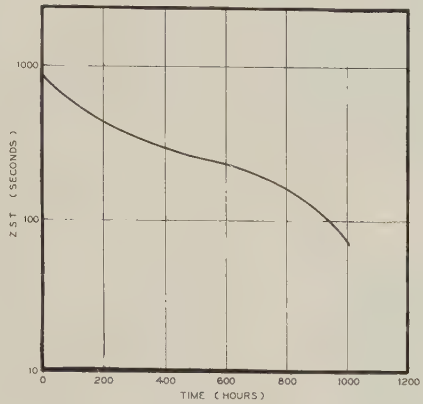


Figure 2, zero-strength-time (ZST) time at 235°C for polychlorotrifluoroethylene.

Experiments at a given temperature which studied the thermal weight loss of a number of polymeric materials did not demonstrate the elevator effect in these polymers with the exception of polyethylene and nylon. Of course, the elevator effect might be observed if other temperatures were used. Further study of the elevator effect exhibited by CTFE indicated that, in general, only polymers prepared using a radiation initiation process consistently showed the elevator effect. A number of stabilizing agents for CTFE were also investigated. The most effective agent was chlorine gas. The chlorine treatment not only prevented thermal discoloration and decreased molecular weight degradation, but also eliminated the elevator effect. This work suggests that trapped free radicals may be responsible for the elevator effect.

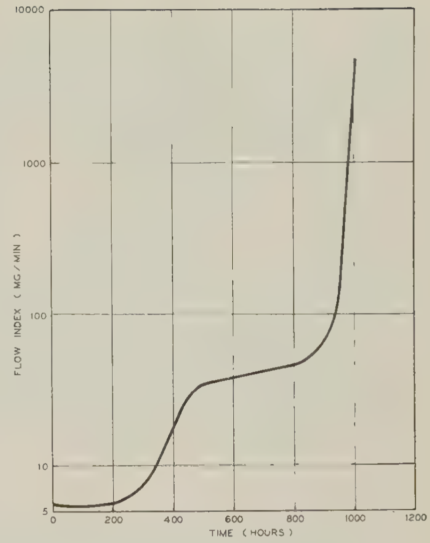


Figure 3, flow index vs. time at 235°C for polychlorotrifluoroethylene.

Association News

Staff Changes in ASTM

Several changes were recently made in the staff of the American Society for Testing Materials. Thomas A. Marshall Jr. was elected executive secretary. He previously was senior assistant secretary of the American Society of Mechanical Engineers. Fred F. Van Atta, formerly assistant secretary of ASTM, was elected treasurer.

Robert J. Painter, formerly executive secretary and treasurer, will continue as consultant to the executive secretary. He will be especially concerned with the Society's long-range planning program. Raymond E. Hess will continue as associate executive secretary. As technical secretary and editor-in-chief, Hess is responsible for the technical activities and publications of the Society.

Dayton Elected Head of American Vacuum Society

Benjamin B. Dayton, Consolidated Vacuum Corp., a subsidiary of Bell & Howell/CEC, has been elected president of the American Vacuum Society. He succeeds Wilfred G. Matheson, Sylvania Electric Products, Inc.

Other officers elected at the Society's national convention in Cleveland were C. Robert Meissner, Georgia Institute of Technology, president-elect; George W. Carr, Vacuum Specialties Co. Inc., treasurer; and Harold C. Weingartner, Arthur D. Little Inc., secretary-clerk.

NISA Protests Monopolistic Trend in Electric Repair Industry

A protest against the encroachment of the General Electric and Westinghouse companies into markets now being served by independent electrical apparatus service companies was lodged by officers of 35 regional, state, and local trade associations attending the Third Annual Chapter Officers Conference of the National Industrial Service Association Inc., at Hotel Coronado, October 15.

According to a resolution unanimously passed by the conference, both manufacturers had advised the U.S. Department of Justice in 1949 that there was "no inclination . . . to conduct an expansive program in the motor repair field." The companies lived up to these commitments for about seven years, but have since "flagrantly disregarded" them by establishing additional service shops in many major trade areas throughout the country, the resolution stated. The resolution called upon the Department of Justice to compel the companies to live up to their commitments and called on members of NISA to enlist the support of their Congressional Representatives and Senators.

Reynolds Is New SPE President

Frank W. Reynolds, IBM Corp., has been elected president of the Society of Plastics Engineers. Other 1961 officers elected at a recent meeting in New York City include: James R. Lampman, General Electric Co., vice-president, engineering; John Delmonte, Furane Plastics Co., vice-president, administration; Maurice F. Malone, Canadian Resins & Chemicals Co., secretary; and John Berutich, Haveg Industries, treasurer. All will take office on January 25, 1961, at the Society's Annual Technical Conference in Washington, D. C. The titles of vice-president, engineering and vice-president, administration (currently first vice-president and second vice-president, respectively) are contingent upon final action in January on a new organization plan for the Society.

Higbee Retained by NEMA to Study Insulated Wire Import Problems

Clarence W. Higbee, who recently retired as assistant general manager, Electrical Conductor Division, Kaiser Aluminum and Chemical Sales Inc., has been retained as a consultant by the National Electrical Manufacturers Association to study import problems affecting the insulated wire and cable industry.

Pixilated Patents

By Mike Rivise

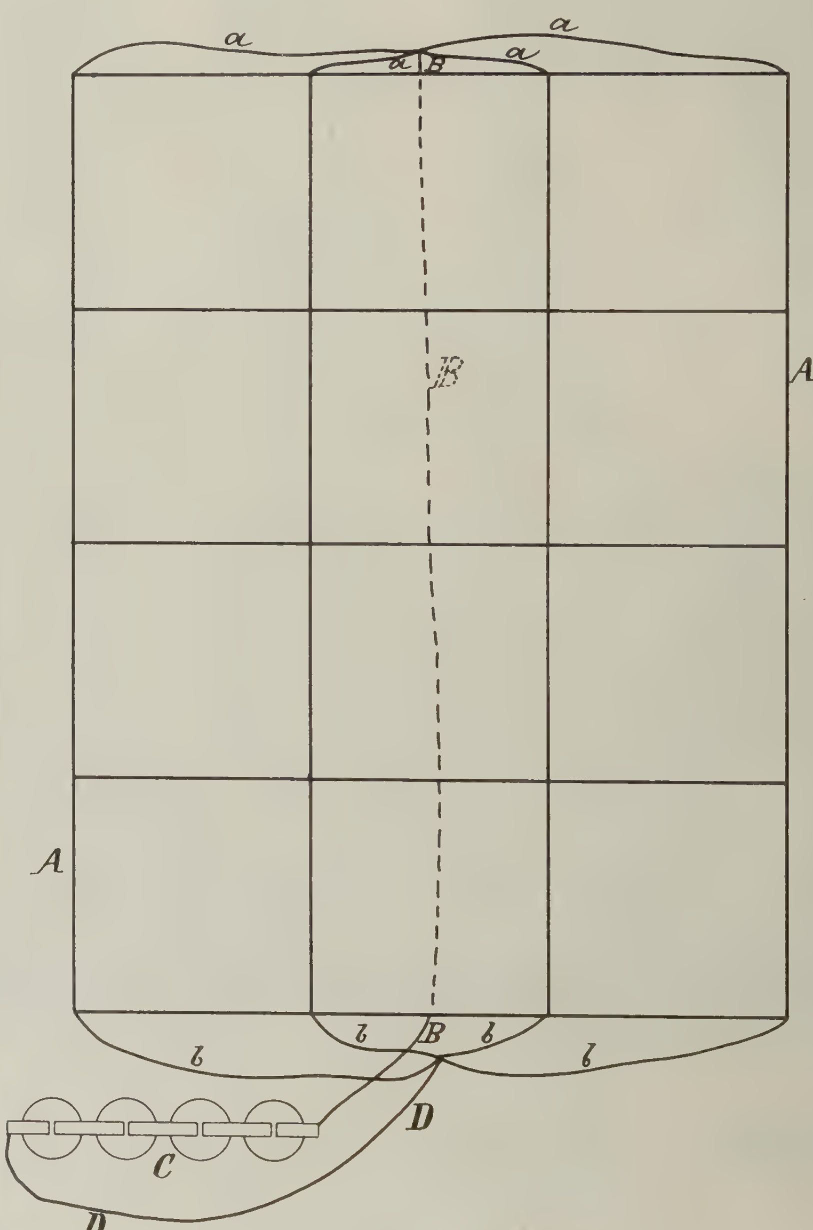
(Forty-eighth in a series of odd and interesting inventions in the electri-onics field from the files of the U. S. Patent Office.)

Readers who are interested in being electrocuted in comfort will find patent No. 285,853 of particular interest. Granted to Rickason Stilwell, New York City, on October 2, 1883, it concerned improvements in means for applying electrical or galvanic currents to beds, couches, mattresses, and the like.

One of the principal improvements was a reduction in cost. Apparently, to obtain such luxury previously, it had been necessary to purchase an entire bed, couch, or mattress designed for this purpose. Rickason's invention consisted very simply of a wire mesh frame-work which could be thrown down wherever this sort of treatment was desired, as long as there was a source of current available.

He seemed quite concerned about getting enough electricity into the unit because he specified that the lead-in wires "may be insulated by an india-rubber or other appropriate coating, when desired, in order that the currents may not be diverted therefrom," but airily dismissed the subject of actual current carried by the wires as "a matter of mere workshop skill."

As a matter of fact, it might be suspected that he either had a limited knowledge of electricity or a rather unorthodox view of it, since he states that the frame-work can be used on a mattress, bed, or couch either above or below the blankets or sheets and that "the passage of the current of electricity in due proximity to the body of the person lying thereon will effect in said person the curative or hygienic results known to be experienced from the application of electricity."

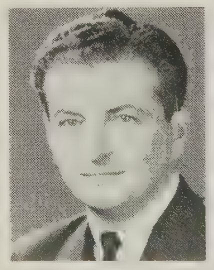


People in the News

T. G. A. Sillers, 57, manager of the power systems engineering department of Allis Chalmers Mfg. Co., died recently in Milwaukee. He joined the firm in 1925. *E. F. Greiwe*, with the company since 1936, and most recently manager of the Norwood, Ohio, works centrifugal pump department, has been named manager of the West Allis centrifugal pump department and compressor department. He is succeeded at Norwood by *R. J. Dineen*, with the firm since 1952. *H. L. Ross* has been appointed manager of engineering for the newly consolidated pump and compressor department. He had been manager of the West Allis centrifugal pump department since 1959.

Edward H. Lewis, president of Western Insulated Wire Co., Los Angeles, died recently in his Brentwood, Cal., home. He founded the company in 1937.

Eugene Jacobson has been elected a vice president of Sun Chemical Corp., New York City. He was the founder and president of Facile Corp., manufacturer of laminated products, until it was sold to Sun last November.



E. Jacobson

J. T. Wilson

Dr. Jack T. Wilson has been appointed to the technical service staff of the Magnet Wire Div., Essex Wire Corp., Fort Wayne, Ind. He previously was chief physicist of the Louis Allis Co., where he directed research and development in insulation materials.

At Chance Vought Aircraft Inc., Dallas, *Gifford K. Johnson*, with the firm 10 years, has been named executive vice president. In the Electronics Div., *D. J. Simmons*, previously chief of ground support systems, has been promoted to the newly created position of chief of electronics systems; and *J. R. Campbell*, formerly staff assistant in electronics engineering and chief of the electronics design section, has been appointed chief scientist.

F. Leonard Bryant, a vice president of Hooker Chemical Corp., Niagara Falls, N. Y., since 1957, has been elected executive vice president and a director. Also elected directors are *Thomas F. Willers*, a Hooker vice president, and *Werner P. Gullander*, executive vice president and a director of General Dynamics Corp.

Formica Corp., Cincinnati laminated and molded plastics manufacturing subsidiary of American Cyanamid Co., has named *Albert L. Munsell* general sales manager and appointed *S. J. Cartier* industrial sales manager.

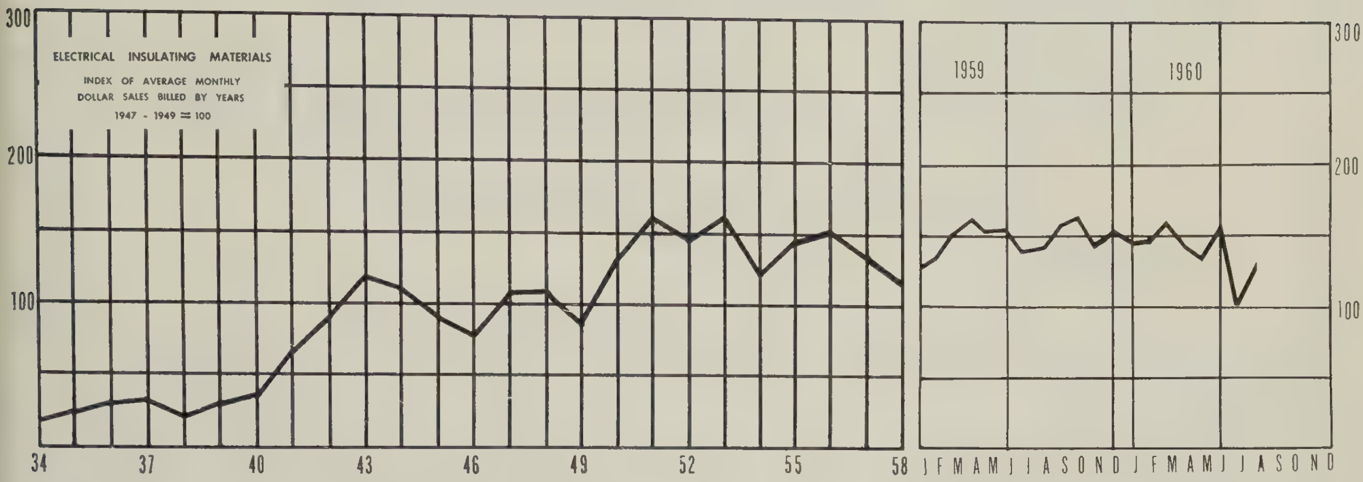
A. Munsell

S. Cartier

Two sales engineers have been added to the Rochester, N. Y., staff of F. J. Stokes Corp., Philadelphia plastic machinery manufacturer. They are *Robert Fehr*, previously manager of plastic machinery sales for Watson-Stillman Div., Farrel-Birmingham Inc., and *Charlton I. Prince*, formerly with the Rochester Products Div., General Motors Corp.

Jack H. Zillman has been elected vice president, data processing division, Consolidated Electrodynamics Corp., Pasadena, Cal., a subsidiary of Bell & Howell Co. He formerly was vice president and general manager Pacific Div., Daystrom Inc. The director of the Analytical & Control Div., *Harold F. Wiley*, has also been named a vice president of the firm. Wiley has been with CE since June 1937, just four months after it was established.

NEMA Electrical Insulation Index



	Aug. '60	July '60	Aug. '59
Index Series	131	101	145
Aug. '60 point change from other mos.		+30	—14
Aug. '60 % change from other months		+30	—10

Index is based on 1947-1949 average month, inclusive=100

Published through the courtesy of the National Electrical Manufacturers Association

Materials Used in Electrical Insulation Index

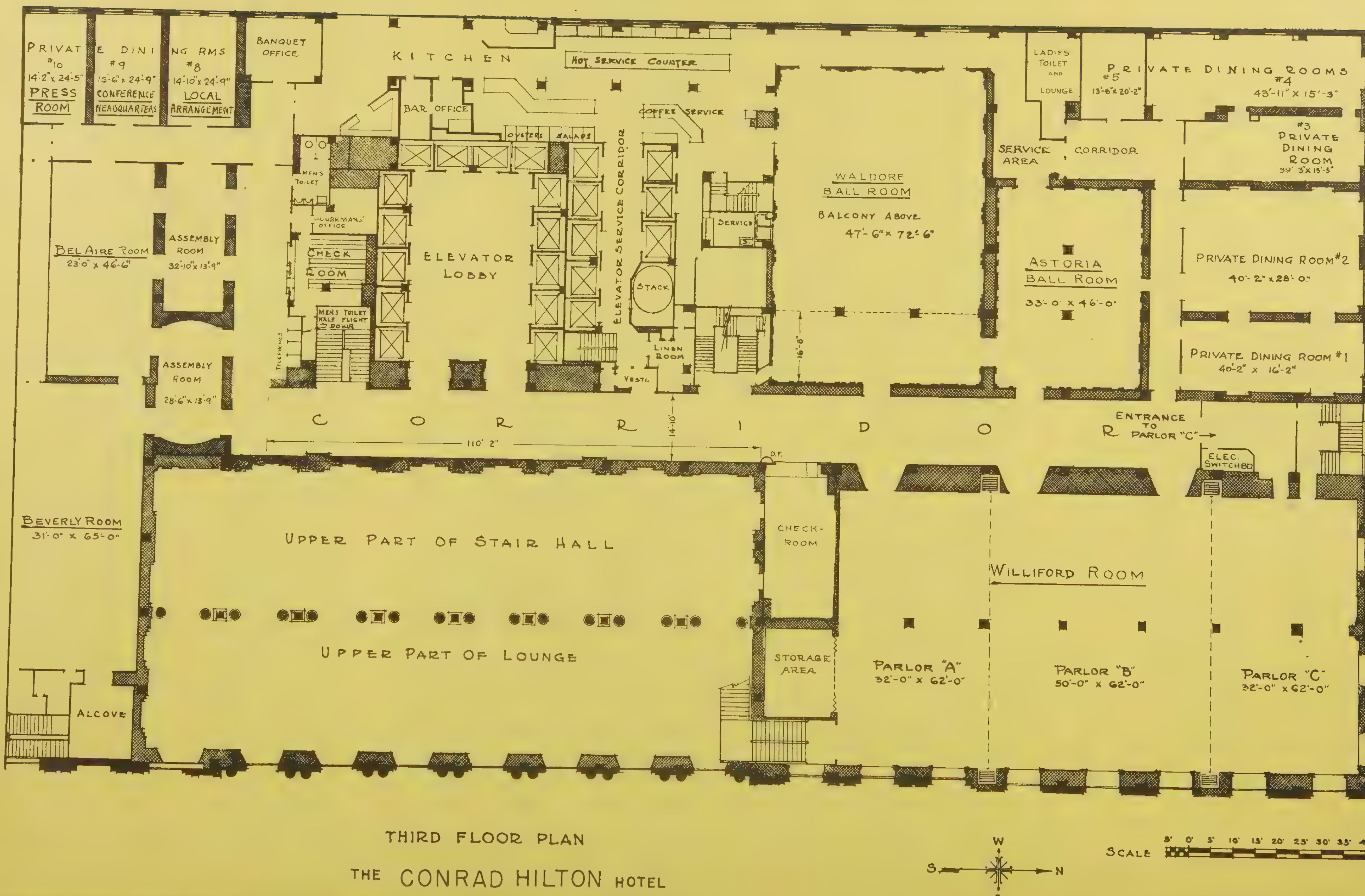
- Industrial Laminated Products
- Manufactured Electrical Mica
- Varnished Fabric and Paper
- Vulcanized Fibre
- Coated Electrical Sleeving

Conference Section

THIRD NATIONAL CONFERENCE ON THE APPLICATION OF ELECTRICAL INSULATION

December 5-8, 1960
The Conrad Hilton Hotel, Chicago

IN THIS SECTION



THIRD FLOOR PLAN

THE CONRAD HILTON HOTEL

NATIONAL CONFERENCE ON APPLICATION OF ELECTRICAL INSULATION

Conference Highlights and General Information

Detailed information on the program, meetings, exhibits, and other features of the Third National Conference on the Application of Electrical Insulation appears elsewhere in this issue. A condensed description of some of the conference features is given here as a quick, overall guide to the December 5-8 meeting in the Conrad Hilton Hotel, Chicago.

The conference is co-sponsored by the American Institute of Electrical Engineers and the National Electrical Manufacturers Association. Anyone with an interest in insulation may attend.

Registration and Tickets

The main registration desk will be located on the second floor. The complete conference registration fee is $15. This includes entrance to all technical meetings, the exhibit hall, and a copy of the preprint booklet. Government employees, educators, and students will be admitted to both technical sessions and exhibits free, but will be charged $1 for the preprint book. The fee for attending only the exhibits is $3.

Tickets for special functions (banquet, luncheons, etc.) may be obtained at the second floor registration desk when registering. If they are not purchased at this time, they may be obtained later at a special ticket booth on the third floor.

Technical Sessions

Technical sessions are organized on the basis of end-use applications. Each session will begin with a keynote paper presented by the session director. Visual aids and discussion-type presentations will be emphasized rather than formal readings. A complete listing of titles, authors, times, and room locations appears on other pages in this issue.

Exhibits

Commercial exhibits by producers of electrical insulation, instruments, etc., will be open during specified hours. For exhibit hours, list of exhibitors, and products or services featured, see the report on other pages in this issue. Exhibits will be free to registrants, with a special fee of $3 being charged those who do not wish to attend the technical sessions and other functions.

Conference Banquet

Again this year, the "Unity of Action" banquet on Tuesday evening will be one of the most significant events of the conference. Many nationally known personalities will be present. Walker L. Cisler, The Detroit Edison Co., will be the featured speaker. Toastmaster will be Clinton B. Burnett, Johns-Manville Corp. Further details appear on another page.

Golden Omega Award

Another banquet highlight will be the presentation of the *Golden Omega* award to Dr. Mervin J. Kelly, who was with Bell Laboratories for 41 years and who is presently serving as a research management consultant to IBM Corp. and Bausch and Lomb Optical Co. The award, sponsored by *Insulation,* is presented annually to a man picked by an independent committee as being outstanding in science and engineering. The recipient last year was Vice Admiral Hyman G. Rickover, USN.

AIEE Luncheon

A luncheon has been scheduled Wednesday under the auspices of the Electrical Insulation Committee of the American Institute of Electrical Engineers. Details appear on another page.

NEMA Dinner and Reception

A dinner and reception sponsored by the National Electrical Manufacturers Association will begin at 6:30 pm Wednesday. Details appear on another page.

Plant Tours and Points of Interest in Chicago

Several tours to nearby facilities of interest to insulation men have been scheduled. Separate trips to Western Electric Co. and the Electro-Motive Div. (GMC) are planned for Monday afternoon. The Motorola Co. will be visited Wednesday afternoon, and a tour to the Allis-Chalmers Co., West Allis, Wisc., will occupy all day Wednesday.

Insulation Marketers' Meeting

The conference will be concluded with a Marketers luncheon on Thursday following the morning Marketing sessions. These sessions will combine inspiration, "how-to-do-it" sales training help, sales management know-how, humor, and "inside" marketing information. Details will be found on another page.

Merchandise Mart—Overlooking Chicago River at Wells.

NATIONAL CONFERENCE ON APPLICATION OF ELECTRICAL INSULATION

Points of Interest in Chicago

Insulation men attending the Third National Conference on the Application of Electrical Insulation will have an excellent opportunity to visit the "undisputed leader" of convention cities. Chicago has earned this title because of its friendliness to visitors and its many social, cultural, and educational attractions.

Located at the foot of Lake Michigan, Chicago has advanced in a little over a hundred years from an obscure Indian outpost to the second largest city in the United States and a major hub of commerce and industry. Its recorded history really begins with the first exploration by Louis Joliet in 1673. A year later, Father Marquette returned to establish a mission for the Indians.

Conrad Hilton Hotel on left, Michigan Avenue, and Art Institute center right.

In 1795, the Government, by a treaty with the Indians, acquired title to a plot of land at the mouth of the Chicago River to establish the famous Fort Dearborn from which the city sprouted.

The downtown section of the city—known by the natives as the "Loop"—offers the visitor various means of transportation for visiting points of interest. In most cases, these attractions are within walking distance, and the ones farther out may be easily reached by el, subway, bus, or taxi.

This list of some of the things to see in Chicago is presented for the convenience of insulation men, who will find it a quick and easy way to plan their free time to best advantage. There is no entrance or tour charge unless a specific fee is stated.

Downtown

Art Institute—Michigan & Adams. Open 9 to 5, weekdays; 12 to 5, Sat. Admission free Wed., Sat., Sun., and holidays.

Board of Trade—Jackson at La Salle. Largest grain exchange in the world. 9:30 to 1:15, Mon. through Fri.; 9:30 to 12, Sat.

Chicago Locks—at mouth of Chicago River. Big enough to float ocean steamers and where St. Lawrence waterway meets Mississippi River system.

Chicago River—Separates downtown and city's north and west sides. Northern outlet of Lakes to Gulf inland waterway system.

Civic Opera—Madison at Wacker. Most palatial auditorium ever conceived. Home of Lyric Opera and traveling ballet groups.

Grant Park—Between the lake and Michigan Ave. from Randolph to 14th St. Built entirely on land reclaimed from the lake.

John Crerar Library—86 E. Randolph. Free reference library of technical and scientific literature.

La Salle Street—From Jackson to Washington. Wall Street of Midwest.

Michigan Ave.—East of Loop. World-famous spot for window shopping.

Midwest Stock Exchange—120 S. La Salle. Open 9 to 2, weekdays; 9 to 2, Sat.

State Street—Main street of Chicago. Home of Marshall Field's, Carson Pirie Scott, and many other department and specialty stores.

North Side

Bughouse Square—Dearborn & Walton. Where soap-box orators gather to let off steam.

Chicago Historical Society—In Lincoln Park at Clark & North. Open 9:30 to 4:30, weekdays; 12:30 to 5:30, Sun. Free weekdays.

Lincoln Park Zoo & Conservatory—Stockton Dr. & Fullerton. Open every day.

Water Tower—Michigan & Chicago Ave. Survivor of Chicago Fire.

South Side

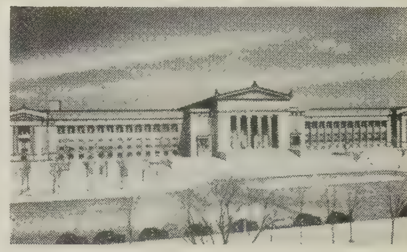
Adler Planetarium—Lake Front at Roosevelt Rd. Weekdays 10 to 5;

Sun. 2 to 5. Admission free Sun., Wed., Sat. Other days, 30¢.

Chicago Natural History Museum—Grant Park at Roosevelt Rd. Open 9 to 4. Admission free on Thurs., Sat., Sun. Other days, 30¢.

George F. Harding Museum—4853 S. Lake Park Ave. Medieval armour. Open 1 to 5 except Mon. and Sat.

Museum of Science and Industry—Lake Front at 57th St. Open weekdays 9:30 to 4, Sat. to 5:30, Sun. to 7.



Admission free except to coal mine, Nickelodeon, captured U-boat, and Microworld Theater.

Oriental Institute—58th and University. Daily 1 to 5.

Shedd Aquarium—Grant Park at Roosevelt Rd. Open 10 to 5. Free Thurs., Sat., and Sun. Other days, 30¢.

Soldier Field—Lake Front at 16th.

Stock Yards—41st & Halsted.

West Side

Garfield Park & Conservatory—3400 to 3800 West, 500 North to 500 South. Open every day.

Maxwell Street—At Halsted. Noisy outdoor market. Closed Sat. Sun. AM best time to go.

NATIONAL CONFERENCE ON APPLICATION OF ELECTRICAL INSULATION

Complete Program: Times, Locations, Titles, and Subjects for All Meetings and Technical Sessions

Conference headquarters, exhibits, registration and information facilities, ticket sales activities, dining functions, and all technical session meeting rooms are located at the Conrad Hilton Hotel in Chicago. Be sure to examine the complete program thoroughly so that you may plan to attend all sessions which interest you.

Conference Headquarters

Private dining room No. 9, 3rd floor.

Local Arrangements Headquarters

Private dining room No. 8, 3rd floor.

Press room

Private dining room No. 10, 3rd floor.

Sunday, Dec. 4

Registration

2 - 9 pm, 2nd floor.

Ticket Sales

2 - 9 pm, 3rd floor.

Monday, Dec. 5

Registration

8 am - 6 pm, 2nd floor.

Ticket Sales

8 am - 6 pm, 3rd floor.

Monday Morning, Dec. 5, Technical Sessions

7:30, speakers' breakfast, private dining room No. 1, 3rd floor.

9-12, Session 1A, Class F Systems for Medium Size Rotating Equipment, Waldorf room, 3rd floor. E. W. Summers, Westinghouse Electric Corp., session director. E. B. Snyder, Bentley-Harris Mfg. Co., session manager.

Review of Class F Insulating Systems, E. W. Summers, Westinghouse Electric Corp. Interest in 155°C materials has been mounting. However, 155°C materials have no historical definition and thus must be determined by functional tests. There is also the question of whether the use of a class F system will be an economic advantage.

End User Discussion, Henry Pollack, Ingersoll Rand Corp.

Flexible Synthetic Fiber Insulating Papers, R. C. Berry, Rogers Corp. Synthetic fiber papers have mechanical properties similar to rag papers but have better chemical resistance, thermal stability, and dielectric strength. Products for hermetic motors and for use at temperatures up to the class F range have been produced.

Flexible 155°C Electrical Insulation, Lloyd N. Smith, New Jersey Wood Finishing Co. This paper covers a flexible, heat-resistant, resin coated glass fabric for use at 155°C. It provides data on heat aging, dielectric strength under heat, weight loss of resin at elevated temperatures, and compatibility properties with various magnet wires.

Enameled Wire Insulation for Class F Systems, R. H. Hall, Phelps Dodge Copper Products Corp. New magnet wire development for class F 155°C service does not heat shock and exhibits better compatibility with varnishes than conventional polyester wires. It has better abrasion resistance, solvent resistance, and a high order of dielectric strength.

Functional Evaluation of Class F Insulation for Rotating Machinery, A. J. Sherburne, J. R. Learn, and Wm. Viscusi, General Electric Co. Modified test models have been devised to simulate random wound and layer wound constructions using combinations of magnet wire, varnish, and ground and layer insulations. A slotette uses a section of an actual stator to compare slot insulations and wrappers in combination with wire and varnish. A modified transformerette evaluates layer insulations and new coil treatments.

9-12, Session 1B, Progress in Switchgear Insulation, Williford room, 3rd floor. D. D. Bergh, General Electric Co., session director. A. J. Briggs, Continental-Diamond Fibre Co., session manager.

Progress in Switchgear Insulation, D. D. Bergh, General Electric Co.

End User Paper, W. K. Anderson, Commonwealth Edison Co.

An Analysis of Insulation Requirements for Metal-Clad Switchgear, Warren Donaldson, General Electric Co. Metal-clad switchgear insulation requires a combination of mechanical properties determined by short circuit forces, electrical properties determined by service voltage and equipment application, and chemical properties determined by service environment and material limitations. An understanding of the basic requirements will help to achieve the optimum material.

Laminated Plastics for Switchgear, H. V. Howe, Continental-Diamond Fibre Corp. Use of epoxy glass tubing in oil and air type circuit breakers, and the conventional use of paper base phenolic tubes for primary disconnect bushings, bus insulation in magnetic air circuit breakers, and interruption housings for oil circuit breaker contacts. Flat, postformed, and molded laminate shapes in metal-clad switchgear also covered.

Compreg in Switchgear, E. T. Rogers, Permali, Inc. This is a definition and description of compreg with a review of properties. There is a general discussion of the function of dielectric components in switchgear with an analysis of the specific requirements of major functional parts.

9-12, Session 1C, Electrical Circuit Connectors, Beverly room, 3rd floor. R. F. Dorrell, Amphenol-Borg Electronics Corp., session director. H. W. Lynch, Moxness Products Inc., session manager.

MIL-C-26500 Connectors, R. F. Dorrell, Amphenol-Borg Electronics Corp. This paper describes the development and fabrication of composite silicone-epoxy dielectric materials which maintain electrical integrity under continuous exposure to high temperature, moisture, fuels, salt corrosion, ozone, and mechanical stresses. This connector construction has eliminated the necessity for using potting compounds.

End User Paper, Galen Eley, Wright Air Development Div.

Insulating Systems for 600°F and 1000°F Aircraft Wire, R. W. Anderson and Allen Hubbard III, Lewis Engineering Co. Program has resulted in the development of insulated wire and cable suitable for use in Mach 3 aircraft and for ambient temperatures ranging from 600°F to 850°F and conductor temperatures from 650°F to 1000°F. The paper summarizes performance data, testing programs, and test equipment.

Epoxy in New Form Molding Compound and Machine Stock, Lloyd A. Dixon, Hysol of California. Epoxy machining stock in sheets, rods, and tubes can be used over a range in excess of −65°F to 400°F for bushings, bobbins, coil forms, inserts, and potting shells. Epoxy molding compounds are available for use in high-speed automatic molding equipment. Molded parts can be produced in less than 100 seconds. Complete physical and electrical data for the molded and the cast products are discussed.

Monday, Dec. 5, Trade Show Exhibits

12 - 9 pm, main exhibition hall, lower lobby.

Monday, Dec. 5, Plant Tours

1 pm, Western Electric Co., Hawthorne Works, rod and wire mill and cable plant, $3.00
1 pm, Electro-Motive Div., General Motors Corp., diesel-electric locomotives and mobile generating units and controls, $3.00

Monday Afternoon, Dec. 5, Technical Sessions

2-5, Session 2A, Medium D-C Rotating Equipment, Waldorf room, 3rd floor. J. L. Kuelthau, Allis-Chalmers Mfg. Co., session director. Ward Hanson, Minnesota Mining & Mfg. Co., session manager.

Newer Insulating Materials in D-C Motors and Generators, J. L. Kuelthau, Allis-Chalmers Mfg. Co. In the last decade the number and variety of insulating materials available have increased many fold. Synthetic resins, fiber glass, reconstituted mica, synthetic fibers, and films in their varied forms and characteristics have provided a wealth of new materials and combinations of materials which have enabled designers to provide greater reliability, greater economy, and wider range of application.

Application Experience on D-C Motors by the United States Navy. W. H. Fifer, Bureau of Ships, U. S. Navy. The Navy has 6,500 large motors and generators which have been in operation for 15 to 18 years. All were constructed with class B insulation. Early problems consisted mainly of toxicity hazard of phenolic parts when burning, reconditioning after flooding in salt water, and improper varnishing procedures. Large motors and generators can be designed for long trouble-free life by proper use of air coolers, carbon dust filters, and suitable enclosures. Any amount of silicones will cause accelerated brush wear and must be avoided in enclosed machines with commutators or slip rings.

Evaluation of Commutator Bar Insulation, M. F. Gerkin, Continental-Diamond Fibre Corp. This presentation evaluates and compares the numerous micaceous materials available for commutator bar insulation with respect to the primary requisites: dielectric strength, compression—both hot and cold—and stability at high pressures and temperatures.

Evaluation of New Materials for D-C Motors and Generators, W. B. Penn, General Electric Co. In addition to, and as a prelude to large scale insulation systems evaluation, a variety of smaller, more rapid screening and evaluation tests are employed in the selection of insulation materials. Some of these tests are described and their results indicated. These include: compatibility tests, dimensional stability or resistance to compression creep of sheet insulations, bonding strength tests on varnishes, and statorette testing of systems.

Epoxy Resin in Tape Form, R. R. Charbonneau and P. L. Hedrick, Minnesota Mining & Mfg. Co. Epoxy resins in tape form in both bondable and fully cured resin types in a wide range of flexibility are described, with specific reference to applications for each. Polyester fibers, glass fibers, mica paper, or mica splittings are used as reinforcement.

2-5, Session 2B, Materials for Upgrading Temperature for Controls, Williford room, 3rd floor. L. Mayeron, Minneapolis-Honeywell Regulator Co., session director. P. L. Hedrick, Minnesota Mining & Mfg. Co., session manager.

Materials for Upgrading Temperature for Controls, L. Mayeron, Minneapolis-Honeywell Regulator Co. There has been an increased demand to upgrade controls for higher operating temperatures. In many cases, this must be accomplished in decreased space. This presents a problem regarding compatibility.

Electrical Insulation in Air Conditioning, A. B. Newton, Borg-Warner Corp., York Division. Even large motors are now enclosed in refrigerant atmospheres, and smaller and more complex controls are in use. Both are made possible through new insulation materials. Their use provides reliable equipment in as little as half the cubage needed previously.

Ultra-Fine Magnet Wires of Copper and Aluminum Open New and Challenging Fields, J. L. McKinley, Rea Magnet Wire Co. Inc., Div. of Aluminum Co. of America. Manufacturing techniques have been developed for low cost, high volume production of film insulated wires 45 and finer in both copper and aluminum. Char-

acteristics are outlined and likely areas for potential developments are pointed out. Problems and techniques required for handling are discussed.

High-Temperature Epoxide Resin Formulations, J. A. Warburton, and R. S. Norman, General Electric Co. This paper covers the formulation and evaluation of high-temperature epoxide resins. Emphasis has been to develop impregnating and encapsulating materials for operation at 232°C and thermal cycling to —65°C. Data are presented on weight loss, dimensional changes, and thermal cycling.

Laminated Mica—a New Insulation Material, E. G. Dingman, The Macallen Co. Inc. New mica reinforced laminate with epoxy resins has good strength at high temperatures, unusually high stiffness, good electrical properties inherent in mica, fire retardance, and a coefficient of expansion that is nearly the same as copper. Properties are good enough to allow the use of 1/32″ to replace 1/16″ XXXP laminates. Copper-clad materials can be had. A similar material is available in tape and sheet form in an uncured condition.

2-5, Session 2C, Electrical Insulation Evaluation, Beverly room, 3rd floor. N. W. Edgerton, Johns-Manville Corp., session director.

Development of Rapid Track Testing Procedures, G. R. Mitchell, The Glastic Corp. A short-time testing procedure has been developed using water filled hypodermic needles as electrodes, which produces a test result in 3 to 5 minutes. This procedure ranks materials in approximately the same order as does the ASTM "Suggested Method," but it may not be as selective for some material compositions. A revised procedure using a controlled spray of contaminated water is also being investigated.

An Interpretation of Arc and Track Resistance Methods by the Power Density Concept, H. R. Sheppard, Westinghouse Electric Corp. The basis of the power density concept is that the carbonization of insulation is a function of the energy expended per unit area of material per unit time. Since each of the test methods now in use employs specific geometrical configurations and defines the amount of electrical energy used in degrading the insulation, the power density concept can be used to interpret and correlate test results.

Functional Evaluation of Mica Products, H. C. Lauroesch, General Electric Co. This evaluation covers the thermal endurance, voltage endurance, handleability, and mechanical properties of mica products as related to application requirements, and the significance of the values obtained.

Evaluation Procedure for Electrical Insulating Varnishes, C. F. Hofmann, Westinghouse Electric Corp. This paper describes the testing methods and presents data used in the evaluation and selection of the new low temperature curing class H insulating varnishes for electrical apparatus. These methods can be modified and are useful for examining all classes of insulating varnishes.

Critical Evaluation of the Accuracy and Reliability of Enameled Wire Tests, R. B. Young, General Electric Co. The reliability of common wire tests has been examined from the viewpoint of variables usually encountered in performing these tests. These variables include humidity, temperature, elongation, and degree of cure of the enamel. Reproducibility of the tests has also been studied. The tests evaluated include scrape abrasion, cut-through temperature, flexibility, solvent resistance, and dielectric strength.

Tuesday, Dec. 6

Registration

8 am - 6 pm, 2nd floor

Ticket Sales

8 am - 6 pm, 3rd floor

Tuesday Morning, Dec. 6, Technical Sessions

7:30, speakers' breakfast, private dining room No. 1, 3rd floor.

9-12, Session 3A, Large Motors and Generators, Waldorf room, 3rd floor. E. S. Yates, General Electric Co., session director. P. A. Goodwin, General Electric Co., session manager.

Large Motor and Generator Insulation Practices, E. S. Yates, General Electric Co. This paper deals principally with machines in the 13.8-kv class. Requirements of high-voltage insulation are reviewed with respect to the finished system and its components, touching on new materials, development, testing, and service performance.

Laboratory Evaluation of High Voltage Stator Insulation, P. E. Podhorez, General Electric Co. This paper describes a laboratory's approach to the evaluation of class B high-voltage stator insulation. It gives a brief description of the test method, sample preparation, and procedure followed. An illustrative example of test results shows the significance of each test.

Low Viscosity Epoxy Impregnants, John Delmonte, Furane Plastics Inc. Solvent-free epoxy formulations proving valuable as impregnants for motors and generators are evaluated. Data on viscosity, physical properties, and cure conditions are presented.

Silicone Insulation Systems and Processes, R. A. Ward and R. S. Armstrong, General Electric Co. Fundamental properties and benefits of sealed silicone insulation systems are presented. Included are data on dielectric integrity and on the effect of system design on moisture resistance. The need for adequate curing is emphasized. Detailed discussion of processing techniques is presented.

Consideration of an Optimum Frequency for High Potential Testing, P. N. Bosworth, General Electric Co. A high potential test at the service frequency is a reliable indicator of the suitability of the insulation system of an electrical apparatus for the service period. However, it is often not possible to apply the service frequency high potential test at field installations. One way to reduce this charging KVA on a given capacitance and test voltage is to reduce the testing frequency. It seems appropriate to discuss preliminary arguments on this subject and to consider if approximately 0.1 cps may be the desired value.

9-12, Session 3B, Application and Evaluation of Transformer Insulating Materials, Williford room, 3rd floor. H. G. Zambell, Allis-Chalmers Mfg. Co., session director. P. M. Di Cerbo, Sterling Varnish Co., session manager.

Application and Evaluation of Transformer Insulating Materials, H. G. Zambell, Allis-Chalmers Mfg. Co. This paper reviews current status of well-known and new insulating materials for oil-filled, gas-filled, and dry type power and distribution transformers—applications; dielectric, thermal, and chemical properties; performance; and economic considerations.

A User Looks at Insulation Materials, A. S. Mickley, Philadelphia Electric Co. Those features of a transformer which a user must examine in making a proper selection are outlined, with particular emphasis on the effects of insulation systems on individual items.

Corona-Free Structures for Dry Type Transformers, C. E. Glatz, Allis-Chalmers Mfg. Co. Detailed studies of the corona inception voltages of models representing solid layer insulation, lead assemblies, and coil clearances were made. The results show that different structures have different corona inception characteristics when corona inception is expressed as a function of the quantity of the charge and as a percentage of breakdown voltage.

Class H Transformerette Test on New Barrier Insulation, Herbert W. Dornbush, Pennsylvania Transformer Div., McGraw-Edison Co. This paper describes preliminary screening work and transformerette tests for evaluation of new class H barrier insulation. New materials provide much longer life at elevated temperatures and greater mechanical strength.

New Magnet Wires for Transformer Use, E. H. Olson, Anaconda Wire and Cable Co. This paper discusses several new magnet wires, and presents data on the unusual features offered by the use of these wires in transformer systems.

9-12, Session 3C, Thermal Endurance of Electrical Insulation, Beverly room, 3rd floor. H. K. Graves, New York Naval Shipyard, session director.

Insulation Life Comparison, Components vs. Systems, H. R. Sheppard and G. A. Mullen, Westinghouse Electric Corp. Test procedures have been developed for use in evaluating insulation systems. In this paper the limitations in designing satisfactory insulation systems based on the evaluation of insulation components are shown.

Thermal Classification of Pressure-Sensitive Adhesive Tapes, R. E. Hudrlik and W. M. Hanson, Minnesota Mining & Mfg. Co. The performance characteristics of various pressure-sensitive electrical tapes have been studied as a function of temperature on a short and long term aging basis. Logarithmic life values are plotted to demonstrate effective tape life in the same manner currently being used to predict insulation life at various temperatures.

Thermal Aging of Enameled Wire and Insulating Varnish, D. L. McClenahan, Schenectady Varnish Co. This paper describes and tabulates the results obtained from a high-temperature modification of both the AIEE #57 method and the proposed Curved

Electrode method for evaluating wire enamels and insulating varnishes.

Overload Resistance of Film Insulated Magnet Wire, R. V. Carmer and E. W. Daszewski, Essex Wire Co. Test procedures for determining the overload characteristics of film insulated magnet wires are described. By resistance heating or oven aging, the test specimens are subjected to temperatures of 240-350°C for short periods of time. Measurements include dielectric strength and the time required for the insulation to change color, smoke, and flow. Also discussed are the effects of film bake and build, wire stretch, and varnish treatment. Results are compared with locked rotor tests on actual units.

The Evaluation of Thermal Endurance of Rigid Electrical Insulation, Kenneth Wechsler, Westinghouse Electric Corp. This paper reviews published data, presents new thermal evaluation data, and discusses a proposed AIEE test procedure for the thermal evaluation of rigid electrical insulating materials.

Tuesday, Dec. 6, Trade Show Exhibits

12 - 6 pm, main exhibition hall, lower lobby.

Tuesday, AIEE No. 511 Working Group Meeting

2 pm, private dining room No. 3, 3rd floor.

Tuesday Evening, Banquet and Award Presentation

6 pm, Unity of Action Reception and Banquet, and Golden Omega Award Presentation, Normandy Lounge and Grand Ballroom, 2nd floor. See details on another page.

Wednesday, Dec. 7

Registration

8 am - noon, 2nd floor.

Ticket Sales

8 am - 6 pm, 3rd floor.

Wednesday, Dec. 7, Plant Tours

8:30 am, Allis-Chalmers Mfg. Co., Wisconsin, manufacture of electric generation and distribution equipment, $6.00.
1:00 pm, Motorola Inc., production of television, radio, and communication systems, $3.00.

Wednesday Morning, Dec. 7, Technical Sessions

7:30, speakers' breakfast, private dining room No. 1, 3rd floor.

9-12, Session 4A, Repair and Maintenance of Rotating Equipment, Waldorf room, 3rd floor. D. E. Stafford, National Electric Coil Co., session director. C. J. Herman, General Electric Co., session manager.

Servicing of Rotating Equipment, D. E. Stafford, National Electric Coil Co. To accomplish economical maintenance and repair extensive specialized techniques and shop facilities are required. These facilities include adequate test and inspection devices, trained personnel, cleaning facilities, machine tool facilities, facilities for manufacturing and installing electrical windings, and adequate impregnation and winding treatment facilities.

Maintenance Testing of Rotating Machinery Insulation, J. C. Botts and J. S. Johnson, Westinghouse Electric Corp. This paper deals with the value of a well planned maintenance program on large rotating apparatus in discerning the types of troubles, contaminants, and degrading influences encountered in service. Discussed are the fundamental principles behind such a program, the actual tests and procedures used for the various insulation components, and the interpretation of such results.

Use and Application of Insulation in Modern Electrical Repair and Service of Rotating Machinery, J. M. Jenkins and J. B. Parker, Reliance Engineering and Mfg. Co. This paper deals with the fundamentals of selecting an inventory of wire, insulation, and impregnants for use in the repair of integral horsepower electrical rotating machinery. This inventory provides the basis from which the repair shop is able to service a multiplicity of equipment.

Magnet Wire for Rewinding Industrial Motors and Generators, R. P. Clark, Phelps Dodge Copper Products Corp. The general shop difficulties encountered with previously available polyester insulations, due to poor windability, heat shock, solvent shock, and cut-thru resistance under heat and pressure are discussed along with the improvements in properties which make practical the use

of a new wire in place of most of the conventional film wires.
Maintenance and Maintenance Testing of Electrical Equipment, K. J. Doll, General Electric Co. The insulation systems in motors and generators are the most critical components which influence reliability. Other factors, aside from electric tests, have to be used and evaluated to come as close as possible to the assurance of motor and generator reliability.

9-12, Session 4B, Guideposts in the Application of Electrical Insulation, Williford room, 3rd floor. G. L. Moses, Westinghouse Electric Corp., session director. E. J. Phelan, Prehler Electrical Insulation Co., session manager.
The Purpose of Electrical Insulation, G. L. Moses, Westinghouse Electric Corp. This paper presents a brief review of what insulation is and how it insulates. The primary function of insulation is described and the important characteristics are discussed. Modern concepts of insulation temperature classification and the general concepts for insulation selection and application are reviewed.
Electrical Insulating Materials, G. C. Gainer, Westinghouse Electric Corp. Electrical insulating materials are defined and somewhat arbitrarily classified according to the mechanics of their intended end-use. A brief discussion is presented concerning the chemical and physical requirements imposed on insulating materials and the contributions of modern polymer chemistry.
The Fundamentals of Insulating Transformers, M. L. Manning, Delta-Star Electric Div., H. K. Porter Co. This paper outlines briefly how insulation is coordinated into a system for dry-type and liquid-filled distribution and power transformers, a review of voltage stresses found in service, and a summary of dielectric tests used to simulate these service conditions.
The Fundamentals of Insulating Motors, Robert Kaplan, The Louis-Allis Co. This deals with the actual use of insulating materials in the motor and discusses the influence on the motor designer or insulation engineer of relatively recent management tools such as automation, data processing, value analysis, and standardization. It also deals with the manner in which the insulation manufacturer can help the designer get what he can use.
The Fundamentals of Insulating Electronic Equipment, K. G. Lagerlof and F. B. Colby, Raytheon Co. The requirements for insulating military electronic equipment differ from those for commercial units in conditions such as miniaturization, high humidity and temperatures, vibration, and thermal shock. Due to size limitations, the higher temperature insulating materials are most commonly used and methods of heat transfer are also an important design feature.

9-12, Session 4C, Printed Wiring Assemblies, Beverly room, 3rd floor. O. D. Black, Radio Corp. of America, session director. Ray Brock, The Richardson Co., session manager.
A Manufacturer Looks at Problems in Insulation Systems in Printed Wiring Assemblies, O. D. Black, Radio Corp. of America. Some of the problems encountered by a manufacturer of printed wiring assemblies are discussed with respect to production difficulties in the use of glass base epoxy laminates. These problems relate to machinability, heat resistance, soldering, repairability, encapsulation and other protective coatings, and environmental testing.
The Importance of Fiber Glass Fabric Finishing and Finish Selection, E. L. Lotz and Alice Eichenbaum, Hess, Goldsmith & Co. For many applications of woven fiber glass fabrics it has been found that the binder applied during the manufacture of the glass fiber is detrimental to the electrical and physical properties of glass plastic laminates. It is necessary to remove the binder and replace it with a finish that will act as a coupling link between the glass surface and the resin. The paper presents a series of tables showing the improvement of three major finishes with epoxy, melamine, and phenolic resin systems.
Epoxy Resin-Fiber Glass Cloth Reinforced Electrical Laminates, Thomas E. Ronay, The Richardson Co. This paper deals with some of the variables which make the term "epoxy-glass laminates" increasingly more meaningless to the design engineer, especially when dealing with performance requirements not included in NEMA specifications for grades G-10 and G-11.
Etched Circuit Board Re-Entrant Coatings for Solder Repairs, D. S. Preston, Hughes Aircraft Co., Communications Div. This paper presents the data and conclusions obtained from evaluating several new epoxy-polyamide and urethane coatings for etched circuit boards. These new coatings possess the desired properties of protection, component support, and are re-enterable for repair by application of solder irons which cause depolymerization or

"shrink-back."
Encapsulation of Printed Wiring Assemblies, J. W. Hawkins, Chemical and Metallurgical Div., General Electric Co. This paper defines an encapsulant, lists some of the materials that are now used and sources of information that will be helpful in selecting the right material or materials. Suggestions for screening the materials are given. The final portion of the paper describes production applications of RTV liquid silicone rubber.

Wednesday, Dec. 7, Trade Show Exhibits

12 - 6 pm, main exhibition hall, lower lobby.

Wednesday, AIEE Luncheon

12:15, Luncheon, sponsored by AIEE Electrical Insulation Committee, open to all registrants, Boulevard room, 2nd floor. See details on another page.

Wednesday, AIEE No. 510 Working Group Meeting

2 pm, private dining room No. 3, 3rd floor.

Wednesday Afternoon, Dec. 7, Technical Sessions

2-5, Session 5A, Foreign Insulation Practices, Waldorf room, 3rd floor. G. L. Moses, Westinghouse Electric Corp., session director.
Insulating Systems Used in Europe, Based on Mica Paper and Thermosetting Resins, Dr. Hans Moismann, The Swiss Insulating Works, Ltd., Switzerland. In order to meet increasing requirements, manufacturers of heavy machinery have abandoned bar insulations formerly used, consisting of mica and thermoplastic resins. New types based on thermosetting resins are used instead.
Insulation Systems in Large Generators in Sweden, C. A. Tengstrand and R. A. Andersson, ASEA, Sweden. The paper discusses the introduction of different synthetic resins in tape insulation and in micafolium to replace natural materials such as asphalt and shellac. Alternate backing materials and new types of mica mat are compared.
Evaluation and Maintenance Testing of Generator Stator Insulation, Dr. Arnold Wichmann, Siemens-Schuckertwerke AG, West Germany. Evaluation of the insulation is made by testing mechanical properties, and electrical and thermal resistivity of the insulating material and the whole system. Loss factor measurements versus voltage and a-c high voltage proof tests are used for checking manufacturing quality of the insulation. Maintenance insulation testing involves the loss factor and d-c values on the winding.
European Testing Practices and Methods, Karl Kiesewetter, Dr. Beck & Co., G.M.B.H., West Germany. Most European countries have committees drawing up general standards, specifications, and test methods for electrical insulating materials. Most testing is directed toward determining individual properties instead of evaluation of systems. Power factor, permittivity, dielectric loss, and life tests are being studied. Environments such as tropical conditions and exposure to refrigeration and oils are also receiving attention.

2-5, Session 5B, Molecular Key to Electrical Insulation Properties, Williford room, 3rd floor. A. E. Javitz, Electro-Technology, session director.
The Need to Know, N. M. Bashara, The University of Nebraska. Two primary factors dictate the need for a basic knowledge of molecular structure by the electrical engineer: (1) optional utilization of electrical insulation under a wide range of conditions in view of constraints other than electrical performance; and, (2) the need for new materials to meet the requirements of new problems.
The Molecular Blocks of Insulating Materials, Jack Swiss, Westinghouse Electric Corp. The general chemical natures of the building blocks or groups of atoms which make up gaseous, liquid, and solid insulating materials are outlined. Some relationships among insulators, conductors, and semi-conductors are mentioned. The methods by which low polymers react to form very large insoluble and infusible molecules are described. The effect of chemical structure and geometry of polymer molecules on some mechanical properties are mentioned and typical structures for insulation materials are shown.
The Relationship of Molecular Structure to Properties of Gaseous

and Liquid Dielectrics, H. B. Pfeiffer, General Electric Co. The relationship of the molecular structure to the electrical properties of liquids and gases is discussed for dielectric breakdown, dielectric constant, dissipation factor, and d-c conductivity.

The Relationship of Molecular Structure to Properties of Solid Dielectrics, Charles R. Vail, Duke University. When dielectric materials are considered as structured assemblages of molecules, their macroscopic properties can be ascribed to the interaction of such structures with three different types of waves: *quantum-mechanical probability, electromagnetic,* and (in the case of crystal lattices) *elastic.* The phenomena of *polarization, magnetization,* and *conduction,* which are of concern to electrical engineers, can be described quite well qualitatively, and with some success quantitatively, in such terms. The dielectric breakdown strength of solids is now sufficiently well understood in terms of molecular structure so that, in certain cases, the synthesis of insulating materials for specific applications has been accomplished.

Molecular Consideration in Selection of Composite Insulating Materials and Insulating Systems, A. J. Warner, Aerovox Corp. It is necessary not only to understand the fundamental behavior of insulating materials per se but to have some concept of the relationships that exist when two or more insulating materials are used in a practical system, especially with other non-insulating materials. A discussion of such phenomena is given using practical examples.

2-5, Session 5C, Missiles and Guidance Systems, Beverly room, 3rd floor. Kenneth Mills, Martin Co., session director. M. L. Lewis, Permacel, session manager.

Environmental Protection of Guidance Modules, Printed Circuits, and Connectors, Kenneth Mills, Martin Co. Military and scientific space flight makes vast demands upon the designers for reliability and miniaturization. Environmental problems encountered in this advanced electronic packaging include temperature variations, torrid to cryogenic, humidity, salt, contamination, chemical compatibility, shock and vibration. This is an introduction to these problems and some of the solutions.

Component Design for High Temperature Environment, L. F. Kilham, Raytheon Co. The newer approaches to component design for high temperature environments are detailed. Techniques described are those which utilize fluorochemical dielectric coolants in the temperature range of 250°C max. At 600°C max, the "Contained Environment" approach is discussed in detail.

Encapsulation of Electrical Components Using Heat Shrinkable, Pre-Molded Parts, P. M. Cook, V. L. Lanza, and J. S. Conde, Rayclad Tubes, Inc. A series of pre-molded rubber and plastic shapes have been developed which, upon the application of heat, shrink and grasp tightly any parts contained therein. Using this technique, a reproducible encapsulation is obtained, offering positive environment isolation and outstanding electrical insulation of even the most non-symmetrically shaped parts. The use of adhesives with this technique results in hermetic seals.

Silicone Encapsulants for Electronic Applications, D. F. Christensen, Dow Corning Corp. The potted capacitor method of evaluating dielectric compounds has been used to evaluate a variety of materials. An inexpensive yet versatile specimen is used with liquid, gel, elastomeric, and filled or unfilled resin embedding compounds. In this work, the following items were of primary concern: 1) Effect of temperature on electrical properties; 2) Effect of aging at high humidity and effect of aging at high temperature on electrical properties.

Polyurethane Foams for Environmental Protection, Richard F. Newkirk, Nopco Chemical Co. Temperature variations, both high and low, humidity changes, shock, and vibration are some of the major problems that have evolved in regard to reliability for electronic packages. The proper selection and correct application of polyurethane foams would solve many of these problems. Urethanes are the lightest functional materials on the market and lend themselves to large production items.

Wednesday, NEMA Insulation Progress Dinner

6:30 pm, reception and dinner, sponsored by NEMA Insulating Materials Division, open to all registrants, Grand Ballroom, 2nd floor. See details on another page.

Thursday, Dec. 8

Ticket Sales

9 am - noon, 2nd floor.

Thursday Morning, Marketing Session

9-12, Session 6, Insulation Marketing Tools for the Sixties, Grand Ballroom, 2nd floor. E. J. Phelan, Prehler Electrical Insulation Co., session director. See additional details on another page.

Marketing Research Contributions and Opportunities in Insulation Markets, Charles P. Mills, Minnesota Mining & Mfg. Co. The nature of marketing research activities and the place and function of marketing research within the company organizational structure are described. Examples are presented of various facets of a marketing survey in order to understand useful techniques. In addition, views are presented concerning means by which dealers, wholesalers, and small manufacturing concerns may take advantage of opportunities for obtaining valuable marketing data.

How to Introduce a New Product, A. L. Baldock, General Electric Co. New product introduction has become more costly and greater risks are involved. There are four basic steps to be taken to reduce these risks and effectively introduce new products: 1) Determine critical customer needs and develop materials to satisfy those needs. 2) Gather complete functional test data on the product. 3) Test market the new product *and* the program for launching the product. 4) Launch the product with a well coordinated sales, promotional and advertising program.

How the Customer Should Treat the Salesman of Electrical Insulation, T. C. Keegan, Federal Insulation Co. This discussion deals with how the customer should handle the salesman, to the advantage of the customer. There are four basic suggestions: 1) Listen to the salesman. 2) Ask his help on technical problems. 3) Work with him on stock and delivery schedules. 4) Earn his confidence in you and your company.

Skit — How to Sell Electrical Insulation, R. E. Joseph, Allis-Chalmers Mfg. Co., W. A. Carlstrom, Insulation Manufacturers Corp., R. W. Swenson, Minnesota Mining & Mfg. Co.

Thursday, Marketing Luncheon and Award Presentation

12 - 2 pm, Luncheon and marketing award presentation to Harry H. Chapman, Jr. Speech by Bill Gove. Boulevard room, 2nd floor. See details on another page.

Close of the Conference

NATIONAL CONFERENCE ON APPLICATION OF ELECTRICAL INSULATION

Unity of Action Banquet to Be Sparked By Cisler, Burnett, Navy Band & Choir, And Golden Omega Award

The success of last year's "Unity of Action" banquet has indeed been an inspiration to committee members who are planning to make this year's dinner an event insulation men won't forget. This important affair will take place Tuesday evening, Dec. 6, at 7:00 in the Grand Ballroom of the Conrad Hilton Hotel. It will follow a reception which will be held in the Normandy Lounge at 6:00.

Highlights of the evening will be the presentation of the *Golden Omega* award to Dr. Mervin Kelly, an address by Walker Lee Cisler, entertainment by the Great Lakes Navy Band and Bluejacket Choir, and the fine toastmastership of C. B. Burnett. The Rt. Rev. Charles L. Street, Suffragan Bishop of the Diocese of Chicago, will deliver the invocation.

Many important guests will be at the head table—leaders of industry and business and important representatives of government, the military, and education.

Entertainment

Musical and vocal programs will be presented by the Naval Training Center Band and the Bluejacket Choir of Great Lakes, Ill. These two famous groups have worked up a program to please every musical taste. The band, directed by Chief Warrant Officer Brumbaugh, has made frequent appearances in concerts, on radio and television, and at numerous dances and celebrations. It is the largest official Navy band in the Midwest and performs readily as a marching unit, concert orchestra, or dance band. The choir, which has a repertoire of more than 700 numbers, will sing a selection of popular and religious songs.

Bishop Street

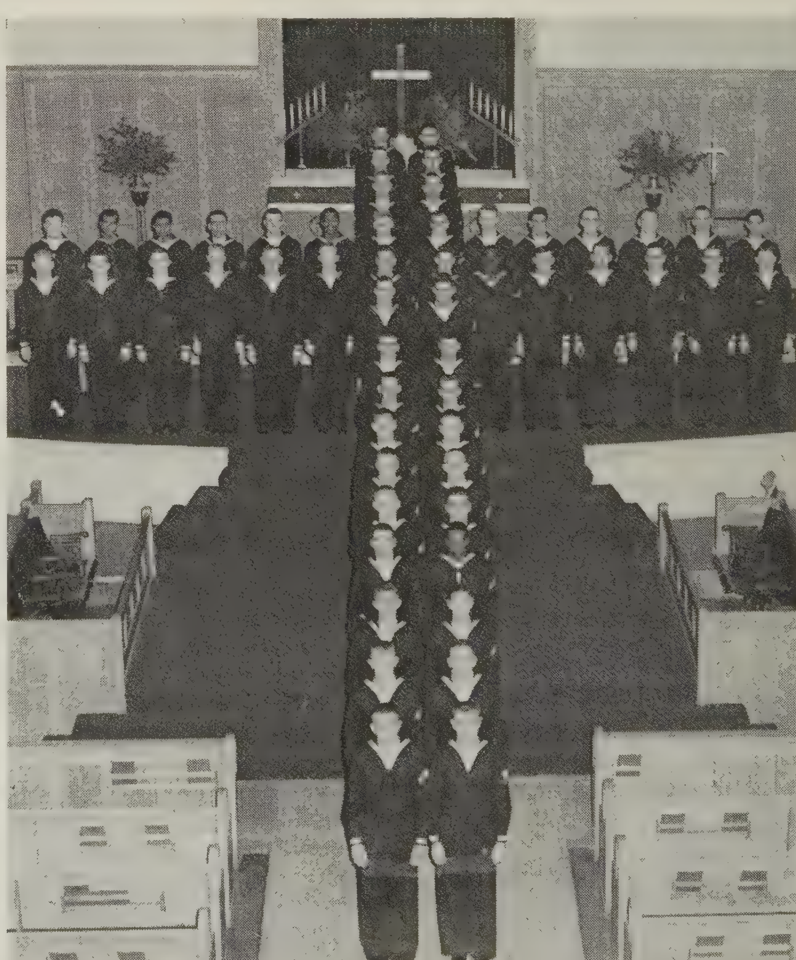
Krone Orchestra

Golden Omega Award to Kelly

One of the outstanding events of the evening will be the presentation of the *Golden Omega* award to Dr. Mervin J. Kelly "in recognition of his outstanding achievements and leadership in the electrical and electronic industries . . . unceasing scientific and administrative contributions to technological progress, the defense of the country, and the promotion of world peace."

In March 1959, Dr. Mervin J. Kelly retired after 41 years of outstanding scientific and administrative service with the Bell Telephone System, the last eight years of which were served as President and, later, Chairman of the Board of Directors of Bell Telephone Laboratories.

One of the nation's leaders in the field of industrial research, he began his Bell System career in 1918 as a research physicist with Western Electric Company's engineering department. His early work was in the areas of thermionic emission, gaseous discharge phenomena, and electron dynamics, and, later, in applications of acoustics in telephony. He served as director of vacuum tube development and as development director of trans-



mission instruments and electronics before being named director of research in 1936. He became executive vice president of the Laboratories in 1944, president in 1951, and chairman of the board in January 1959. In 1948, Bell Laboratories announced the development of the transistor, marking the birth of the semi-conductor industry.

Beginning in 1938, Dr. Kelly was increasingly active in research and development for the military. In World War II, he directed more than 1200 projects for the armed forces. For his services he was awarded the Presidential Certificate of Merit.

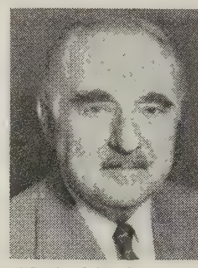
The purpose of this award is to provide national recognition for outstanding achievements, efforts, and contributions to technological progress. Unlike other scientific awards, the *Golden Omega* award is not limited to any particular scientific field. It is made on behalf of America's men of science and industry and the users and producers of electrical insulation. It is sponsored by *Insulation.* Last year, the award was presented to Vice Admiral Hyman Rickover, USN.

Selection Committee

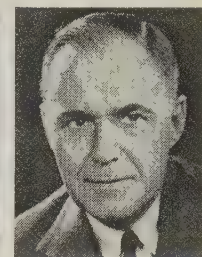
Four leaders, representing industry, AIEE, and NEMA, made up the committee to select this year's recipient. They are: Harold Boeschenstein, President and Director of Owens-Corning Fiberglas Corp.; Clinton B. Burnett, President and Chief Executive Officer of Johns-Manville Corp.; Clarence H. Linder, President, American Institute of Electrical Engineers; and N. J. MacDonald, 30th President of the National Electrical Manufacturers Association.

C. H. Linder

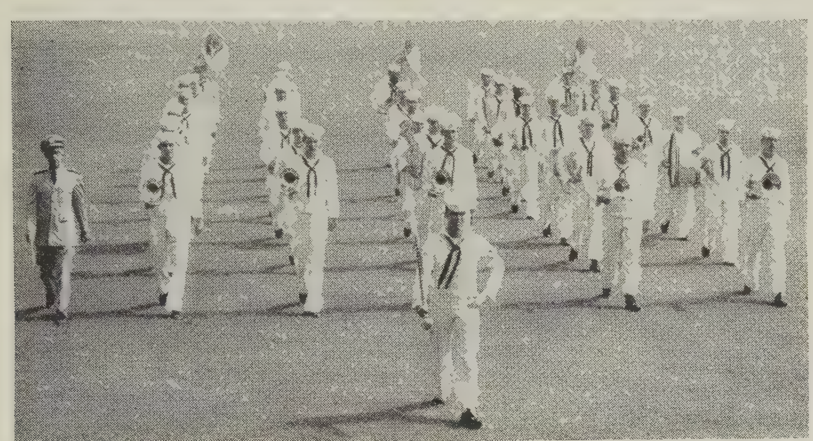
Clinton B. Burnett



N. J. MacDonald



H. Boeschenstein



Dr. Mervin J. Kelly

Harold Boeschenstein has been an active and prominent figure in the glass industry for over 30 years. His emphasis on diligent research and aggressive selling has been a key factor in the remarkable growth of Owens-Corning Fiberglas Corporation of which he has been president since its formation in 1938. He is a member of the Business Advisory Council of the U.S. Department of Commerce and a director of many leading American corporations.

Clinton B. Burnett has had more than 28 years experience in production, engineering, cost reduction, planning and administration at Johns-Manville Corporation. Since joining the company in 1931, he moved rapidly upward, heading various J-M divisions throughout his career. More recently, he became Executive Vice President and a Director in 1957, and President in 1960, and on April 1, 1960, he assumed additional responsibilities as Chief Executive Officer.

Since joining the General Electric Company in 1924, Clarence Linder

has managed both engineering and manufacturing operations, ranging from heavy apparatus to consumer goods. In 1950, he was named General Manager of the company's activities in the large appliance field. From 1953 to 1959 he was Vice President (Engineering) and a member of G-E's Executive Office. He assumed his present position early in 1960. He was named a director of AIEE in 1956 and became its president this year.

N. J. MacDonald has had a long and active career in the electrical industry, climaxed by his election as President of The Thomas & Betts Company and as NEMA's 30th president. As Chairman of the Aircraft Electrical Council, he headed a program that combined the thinking of the aircraft and electrical industries for the first time. In both 1959 and 1960 he was Chairman of the Industry Committee for the observance of National Electrical Week.

Cisler to Address Banquet

The principal speaker of the evening will be a man who has spent his entire business career in the electric power industry. Following his graduation from Cornell University in 1922 with a Mechanical Engineering degree, Walker Lee Cisler became associated with the Public Service Electric and Gas Company, advancing to the position of Assistant General Manager of the Electric Department.

He left in 1943 to become Chief Engineer of Power Plants for The Detroit Edison Company. He was elected Executive Vice President in 1948, a Director in 1951, and President at the end of 1951. In 1954, the duties of the chairman of the board were incorporated with those of president.

He has been actively engaged in atomic energy development since the end of World War II, having served as executive secretary of the AEC Industrial Advisory Group and as an advisor on the U.S. Delegation to the International Conference on the Peaceful Uses of Atomic Energy in Geneva.

He has been decorated by seven European governments and by the United States for his contributions in their behalf both during and since the war. He holds seven honorary degrees from universities and colleges and has received many awards, including the George Westinghouse Gold Medal, the Henry Lawrence Gantt Award, the Washington Award, and the George W. Goethals Award.

Walker Lee Cisler

NATIONAL CONFERENCE ON APPLICATION OF ELECTRICAL INSULATION

AIEE Lunch

This year, the AIEE Luncheon will be held in the Boulevard Room of the Conrad Hilton Hotel on Wednesday, December 7, at 12:15 pm. The luncheon speech on foreign insulation practices—which will kick-off that afternoon's session featuring various European speakers—promises to attract a very large audience. Tickets to the luncheon are $5.00 each and will be on sale at the third-floor ticket booth.

European Technology and Trends in Insulation will be the title of the luncheon speech given by Dr. Richard Vieweg of the Physikalisch-Technische Bundesanstalt, Braunschweig, Germany.

Starting with the impression of the electrical insulation industry which he had during his first visit to Chicago, 30 years ago, Dr. Vieweg will give a short scientific survey on the present situation in the different regions of voltages and currents.

He will then go on to comment on the remarkable progress of synthetic macromolecular insulating materials and tell how they have been excellent, highly specialized solutions to technical problems. At the same time, he will discuss the extended service they have rendered to general technology.

Dr. Vieweg will also tell how the European appreciates the open-minded readiness with which an American grants opportunities to explore new materials. In Europe, perhaps precision and measuring techniques have some priority as far as evaluation of new materials is concerned.

The viewpoints of both continents are of great importance within the standardization framework. The common international development of standards becomes an actual task under the aspect of a growing technological and industrialized globe.

NATIONAL CONFERENCE ON APPLICATION OF ELECTRICAL INSULATION

Insulation Marketing Tools For the Sixties Meeting and Luncheon

All men concerned with marketing, distributing, specifying, and purchasing electrical insulation materials will again have a rare opportunity to get the latest, practical know-how on subjects directly related to their work at the Marketing Meeting, Thursday, December 8th.

This meeting is a down-to-earth, shirtsleeve session that will inspire, amuse, and educate everyone concerned with the sale or specification of electrical insulation. It will begin at 9:00 in the Grand Ballroom of the Conrad Hilton Hotel and will be followed by a luncheon at which the Marketing Award Presentation will take place. Luncheon tickets at $5.00 each will be on sale at the third-floor ticket booth for registrants who have not already obtained tickets.

This year's meeting and the luncheon promise to be informative and exciting and to attract a large attendance. So be sure to plan to attend.

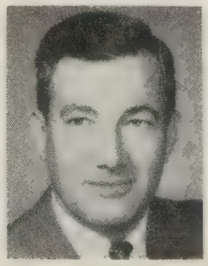
9:00 am—Marketers' Session, Grand Ballroom

Marketing Research Contributions and Opportunities by Charles P. Mills, Marketing Dept., Electrical Products, Minnesota Mining and Mfg. Co., St. Paul, Minn. Here is a vital subject presented in such a manner that it will be useful to both big and small producers and distributors. Actual examples of surveys will be discussed, and useful techniques will be explained . . . by a man who has over 30 years sales experience in the electrical industry.

How to Introduce a New Product by A. L. Baldock, Manager-Marketing, Insulating Materials Department, General Electric Co., Schenectady, N.Y. The insulation field is becoming more and more complex with a constant succession of new products. How you can make sure your new product will stand out . . . what you can do to test-market it in advance . . . and what sales and advertising efforts are needed to successfully launch it . . . are all explained by a salesman who got his feet wet selling silicone insulation in its infancy.

How the Customer Should Treat the Salesman of Electrical Insulation by T. C. Keegan, Jr., President, Federal Electrical Insulation Company, Chicago. Thousands of words have been spoken and printed on how customers should be treated. Finally, here comes a well-known authority with the courage to tell customers how they should treat salesmen . . . and in the process, both the customer and the salesman will learn how he can do a better job. Here's an "eye-opener" by a man with some strong ideas on the subject.

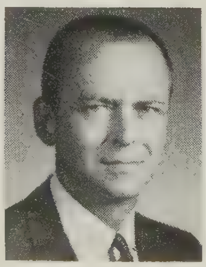
How NOT to Sell Electrical Insulation by the Merry Insulation Player Troupe and Marching and Chowder Society (R. E. Joseph, Purchasing Agent—Electrical Section, Industries Group, Allis-Chalmers Mfg. Co., Milwaukee, Wis.; W. A. Carlstrom, Merchandising Division, Insulation Manufacturers Corp., Chicago; and R. W. Swenson, Minnesota Mining and Mfg. Co., Bedford Park, Ill.). You'll enjoy the heartiest laughs of your life . . . and also learn something about the fine old-fashioned (and nearly forgotten) art of selling . . . as you

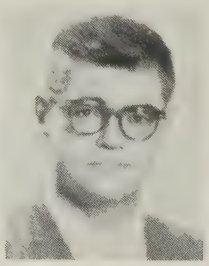

Baldock


Carlstrom


Chapman


Gove


Joseph


Keegan


Mills


Phelan


Swenson

see an honest-to-goodness purchasing agent and salesmen go through their paces. All culture-loving insulation men will acclaim their performance. *Extra-added attraction:* Sassafras Slopkiss, the sweet, pretty, and desirable-looking young secretary, will be the fourth member of this delightful cast.

12:00 noon—Marketers' Luncheon, Boulevard Room

Toastmaster — Edward J. Phelan, Chairman, Marketers' Meeting.
Marketing Award Presentation by E. J. Phelan to Harry H. Chapman, Jr., Manager, Transportation Products Sales Div., Owens-Corning Fiberglas Corp.
There'll Never Be Another You, Luncheon Speech, by Bill Gove, nationally known sales consultant and guest lecturer. Bill Gove is a truly inspirational speaker—one of those rare, gifted men who will have you laughing one minute and nearly in tears the next. The National Sales Executives elected him "Salesman of the Year" in 1954. His talk will be a fitting climax to a session which you will long remember.

> *E. I. Marketers' Award*
> *presented to*
> *Harry H. Chapman, Jr.*
> *in recognition of his many outstanding contributions to foster and promote the advancement of modern marketing techniques in the field of electrical insulation.*
> *In appreciation of his demonstrated willingness to devote his time and talents toward the development and establishment of standards consistent with the high levels of attainment set as industry goals.*
> *And, in gratitude for his unselfish sharing of knowledge and experience to help in furthering the cause of our industry's advancement.*

ei

NATIONAL CONFERENCE ON APPLICATION OF ELECTRICAL INSULATION

NEMA Insulation Progress Dinner

The role of insulating materials in today's rapidly expanding Space Age will be the theme of the First Annual Insulation Progress Dinner, sponsored by the National Electrical Manufacturers Association and held in conjunction with the Third Annual Conference on the Application of Electrical Insulation.

The dinner is scheduled for 7:30 pm, Wednesday, December 7, in the Grand Ballroom of the Conrad Hilton and will follow a reception which starts at 6:30. Exhibits describing the purposes and activities of NEMA will be on view in the room where the dinner will be held. Eugene R. Perry, President of National Vulcanized Fibre Co., Wilmington, Del., will preside.

Highlight of the evening will be a talk illustrated by color slides on the subject, *The Applications of Electrical and Electronic Equipment in Missile Launching,* given by Major M. E. Griffith, Chief of Test Operations for the U.S. Air Force Ballistic Missile Division, Cape Canaveral, Fla.

Major Griffith will give some of the answers to the perplexing materials problems in the Space Age, as well as the latest, official information on the Nation's progress in missiles. There will be an opportunity for questions from the audience following his presentation.

Tickets for dinner and cocktails are $10.00 each. Those who haven't ordered them may obtain tickets at the third-floor ticket booth.

NATIONAL CONFERENCE ON APPLICATION OF ELECTRICAL INSULATION

Men in the Insulation Conference

Many men (and many secretaries) have given unselfishly of their time and efforts to make this year's Conference on the Application of Electrical Insulation a success. Because of space limitations, only most of those who worked in some official capacity can be listed. While the gratitude felt by others in the industry cannot be expressed to all who helped, all conference workers can feel deep satisfaction in knowing that they have contributed to progress in electrical insulation. And to all those who deserve to be listed below but who were not . . . our sincere apologies.

General Conference

Chairman, *W. G. Hoffer*, Sales Manager, Electrical Insulations, Johns-Manville Sales Corp., New York.

Vice Chairman — Commercial, *Michael Nakonechny*, Electrical Industry Sales, Dow Corning Corp., Englewood Cliffs, N.J.

Vice Chairman—Technical, *Roger B. White*, President, The Glastic Corp., Cleveland.

Assistant to the Chairman, *Fred Huber, Jr.*, Staff Engineer, National Electrical Manufacturers Association, New York.

Program

Chairman, *Thomas F. Hart*, Product Manager—Fluids, Silicones Div., Union Carbide Corp., New York.

Assistant Chairman—Distribution Apparatus, *E. O. Hausmann*, Vice President—Technical Director, Continental-Diamond Fibre Corp., Newark, Del.

Assistant Chairman—Rotating Equipment, *J. S. Hurley, Jr.*, Specialist, Electrical Insulation, Silicone Products Dept., General Electric Co., Waterford, N.Y.

Assistant Chairman—Electronics, *Herbert C. Smith*, Marketing Manager, Micarta Div., Westinghouse Electric Corp., Hampton, S.C.

Commercial Exhibits

Chairman, *Arnold E. Bohn*, Electrical Industry Sales, Dow Corning Corp., Englewood Cliffs, N.J.

Assistant Chairman, *W. F. Michener*, Marketing Director, L. Frank Markel & Sons, Norristown, Pa.

Assistant Chairman, *W. J. Dwyer*, Executive Vice President, Suflex Corp., Woodside, N.Y.

John D. Mayes, Sales, John C. Dolph Co., Monmouth Junction, N.J.

A. N. Towne, Market Development Specialist, Insulating Materials Dept., General Electric Co., Schenectady, N.Y.

Technical Exhibits

Chairman, *Charles B. Leape*, Engineering Manager, Micarta Div., Westinghouse Electric Corp., Hampton, S.C.

Promotion and Publicity

Chairman, *Geoffrey F. Brown*, Advertising Manager, Silicones Div., Union Carbide Corp., New York.

Vice Chairman — Exhibitor Promotion, *Robert S. Bloor*, Account Supervisor, Advertising Dept., Dow Corning Corp., Midland, Mich.

Vice Chairman—Publicity, *Frank C. Osterland*, Supervisor of Sales Promotion, Motor & Generator Dept., Power Equipment Div., Allis-Chalmers Mfg. Co., Milwaukee.

Joseph J. McLoughlin, Manager, Sales Promotion, Taylor Fibre Co., Norristown, Pa.

Publications

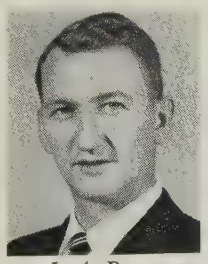
Chairman, *W. H. Bartlett*, Manager, Electrical Products, Johns-Manville Sales Corp., New York.

Assistant Chairman, *R. W. Marien*, Direc-

C. Christiansen

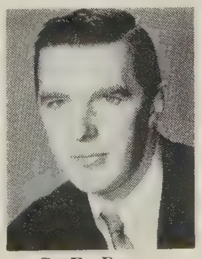
E. H. DaCosta

W. H. Bartlett

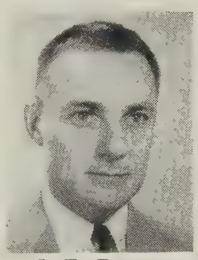


J. A. Bente

E. L. Brancato



G. F. Brown



J. F. Dexter

W. J. Dwyer

Robert S. Bloor

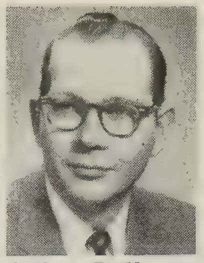
Arnold E. Bohn

Harry C. Burger

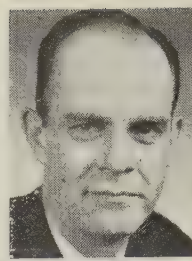
H. H. Chapman

G. F. Fratto

A. S. Gray



Robert R. Hanna

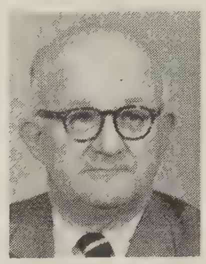


Thomas F. Hart

R. W. Marien

J. H. Martin

J. P. Haughney

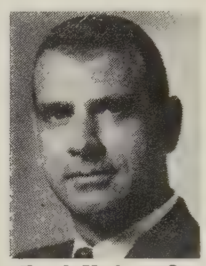


E. O. Hausmann

K. N. Mathes

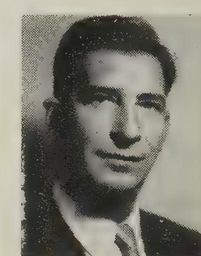
W. F. Michener

W. G. Hoffer

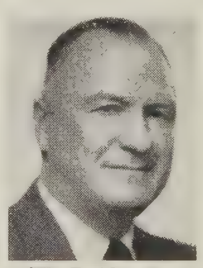


Fred Huber, Jr.

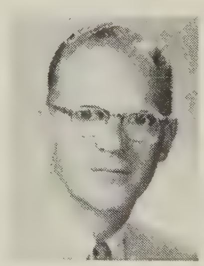
C. W. Miller



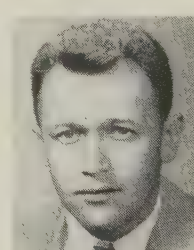
J. F. Miller



W. F. Hugger



J. S. Hurley



M. Nakonechny

C. O. Newlin

T. C. Keegan

C. B. Leape

F. C. Osterland

J. R. Perkins

Peter McKinney

J. McLoughlin

E. R. Perry

E. J. Phelan

tor of Advertising and Public Relations, Sun Chemical Corp., New York.

Banquet

Chairman, *Walter F. Hugger*, General Sales Manager, Electro-Technical Products Div., Sun Chemical Corp., Nutley, N.J.
Assistant Chairman, *H. H. Chapman, Jr.*, Manager, Transportation Sales, Owens-Corning Fiberglas Corp., Toledo, Ohio.

Marketing Meeting and Luncheon

Chairman, *E. J. Phelan*, General Manager, Prehler Electrical Insulation Co., Chicago.
Assistant Chairman, *Thomas C. Keegan, Jr.*, President, Federal Insulation Co., Chicago.
Robert McKeown, General Manager, Robert McKeown Co., Livingston, N.J.
T. W. Osborne, President, Andrew Gilchrist, Ltd., St. Laurent, Quebec, Canada.

Treasurer

Charles O. Newlin, Vice President, Continental Illinois National Bank and Trust Co. of Chicago.
Assistant to the Treasurer, *Michael Lamont*, Apparatus Insulation Sales Manager, Owens-Corning Fiberglas Corp., New York.

Local Tours

Chairman, *Donald W. Stewart*, Chicago Branch Manager, National Vulcanized Fibre Co., Broadview, Ill.
Assistant Chairman, *Melvin W. Snover*, Sales, Hollingsworth & Vose Co., Chicago.

Local Arrangements

Chairman, *Lincoln R. Samelson*, Publisher, *Insulation, Insulation Directory/Encyclopedia*, and *Plastics Design & Processing*, Lake Publishing Corporation, Libertyville, Ill.
Honorary Chairman, *A. S. Gray*, General Manager and Administrative Vice President, The Macallen Co., Newmarket, N.H., and Insulation Manufacturers Corp., Chicago.
Assistant Chairman, *J. H. Martin*, Executive Vice President, Inmanco Manufacturing Div., Insulation Manufacturers Corp., Chicago.
Registration Chairman, *A. J. Wiltjer*, Midwestern Region Manager, Silicones Div., Union Carbide Corp., Chicago.
Registration, *John A. Bente*, Regional Sales Manager, Micarta Div., Westinghouse Electric Corp., Chicago.
Registration, *William Burns*, Prehler Electrical Insulation Co., Chicago.
Registration, *Robert R. Hanna*, Manager, Wire and Cable Sales, Owens-Corning Fiberglas Corp., New York.
Registration, *Curt Jones*, Owens-Corning Fiberglas Corp., Chicago.
Registration, *F. Peter Mignin*, *Insulation*, Lake Publishing Corp., Libertyville, Ill.
Registration and NEMA Dinner Liaison, *J. C. Richardson*, Secretary and Advertising Manager, The Richardson Co., Melrose Park, Ill.

Registration, *J. J. Secor, Jr.*, Manager, Electrical Insulation Sales, Johns-Manville Sales Corp., Toledo, Ohio.

Registration, *Robert F. White*, Union Carbide Corp., Chicago.

NEMA Dinner Liaison, *Harry C. Burger*, Assistant to the Vice President and General Manager of Plastics Div., The Richardson Co., Melrose Park, Ill.

Banquet Ticket Sales Chairman, *John E. Byrne*, President, J. J. Glenn & Co., Chicago.

AIEE Luncheon Liaison, *J. P. Haughney*, Supervising Chemist, Insulating Varnishes, Sherwin-Williams Co., Chicago.

Hotel Arrangements Chairman, *George F. Fratto*, Regional Sales Manager, The Glastic Corp., Chicago.

Press Liaison, *Peter McKinney*, Manager—Chicago Office Public Relations Dept., Union Carbide Corp., Chicago.

Press Liaison, *Richard Morehart*, Fensholt Advertising Agency, Inc., Chicago.

Signs Chairman, *Fred L. Thompson*, Sales, Essex Wire Corp., Chicago.

Exhibits Liaison, *R. G. Tiffany*, Electrical Industry Sales, Dow Corning Corp., Chicago.

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Chairman, *E. R. Perry* (NEMA), President, National Vulcanized Fibre Co., Wilmington, Del.

E. H. DaCosta (NEMA), Vice President, Taylor Fibre Co., Norristown, Pa.

K. N. Mathes (AIEE), Insulation Systems Engineer, General Electric Co., Schenectady.

William F. Michener (NEMA), Marketing Director, L. Frank Markel & Sons, Norristown, Pa.

C. W. Miller (AIEE), Division Manager, Large Power Transformer Engineering, Westinghouse Electric Corp., Sharon, Pa.

Clement S. Schifreen (AIEE), Cable and Insulation Research Engineer, Philadelphia Electric Co., Philadelphia.

Executive Committee

Chairman, *W. G. Hoffer*, Sales Manager, Electrical Insulations, Johns-Manville Sales Corp., New York.

E. L. Brancato, Head, Insulation Section, Solid State Div., U. S. Naval Research Laboratory, Washington, D.C.

H. H. Chapman, Jr., Manager, Transportation Sales, Owens-Corning Fiberglas Corp., Toledo, Ohio.

C. L. Christiansen, Vice President in Charge of Promotion, Golden Years Research and Development Center, Ridge Manor, Fla.

W. F. Hugger, General Sales Manager, Electro-Technical Products Div., Sun Chemical Corp., Nutley, N.J.

Charles B. Leape, Engineering Manager, Micarta Div., Westinghouse Electric Corp., Hampton, S.C.

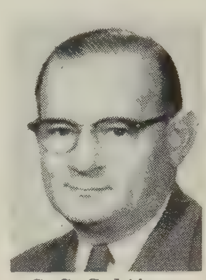
K. N. Mathes, Insulation Systems Engineer, General Electric Co., Schenectady.

J. R. Perkins, Electrical Consultant, Polychemicals Dept., E. I. du Pont de Nemours & Co., Inc., Wilmington, Del.

Lincoln R. Samelson, President, Lake Publishing Corporation, Libertyville, Ill.

J. Richardson

L. R. Samelson



C. S. Schifreen

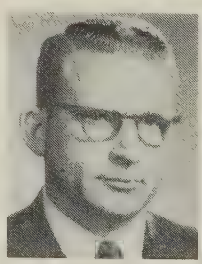
J. J. Secor

H. C. Smith

M. W. Snover

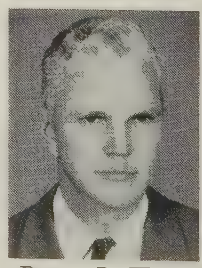
E. B. Snyder

D. W. Stewart



R. G. Tiffany

A. N. Towne



Roger B. White

A. J. Wiltjer

Incoming Officers

General Conference Chairman, *Roger B. White*, President, The Glastic Corp., Cleveland.

Vice Chairman—Commercial, *Arnold E. Bohn*, Electrical Industry Sales, Dow Corning Corp., Englewood Cliffs, N.J.

Vice Chairman—Technical, *E. L. Brancato*, Head, Insulation Section, Solid State Div., U. S. Naval Research Laboratory, Washington, D.C.

Executive Committee Member, *Michael Nakonechny*, Electrical Industry Sales, Dow Corning Corp., Englewood Cliffs, N.J.

Executive Committee Member, *Edward Burns Snyder*, Vice President and Chief Engineer, Bentley-Harris Manufacturing Co., Conshohocken, Pa.

AIEE Electrical Insulation Committee Officers, 1960-61

Chairman, *J. F. Dexter*, Head, Electrical Development and Testing Section, Product Engineering Laboratories, Dow Corning Corp., Midland, Mich.

Vice Chairman, *J. R. Perkins*, Electrical Consultant, Polychemicals Dept., E. I. du Pont de Nemours & Co., Inc., Wilmington, Del.

Secretary, *W. W. Pendleton*, Research Engineer, Anaconda Wire & Cable Co., Muskegon, Mich.

Sponsoring Body Representatives

National Electrical Manufacturers Association, *J. F. Miller*, Managing Director, New York.

American Institute of Electrical Engineers, *R. S. Gardner*, Assistant Secretary, Technical Activities, New York.

NEMA Insulating Materials Division Officers and Directors

Chairman, *E. R. Perry*, President, National Vulcanized Fibre Co., Wilmington, Del.

First Vice Chairman, *D. J. O'Conor, Jr.*, President and General Manager, Formica Corp., Cincinnati.

Second Vice Chairman, *R. L. Westbee*, Vice President, Irvington Div., Minnesota Mining and Manufacturing Co., St. Paul.

W. H. Bentley, Jr., President, Bentley-Harris Manufacturing Co., Conshohocken, Pa.

E. H. DaCosta, Vice President, Taylor Fibre Co., Norristown, Pa.

Roy J. Gavin, General Manager, Irvington Div., Minnesota Mining and Manufacturing Co., St. Paul.

E. O. Hausmann, Vice President—Technical Director, Continental-Diamond Fibre Corp., Newark, Del.

Sinclair H. Kerr, President, The Star Porcelain Co., Trenton, N.J.

W. K. Lydic, Manager, Electrical and Industrial Textile Sales Div., Owens-Corning Fiberglas Corp., New York.

E. M. Markel, General Manager, L. Frank Markel & Sons, Norristown, Pa.

Jay G. Somers, General Manager, Consoweld Corp., Wisconsin Rapids, Wis.

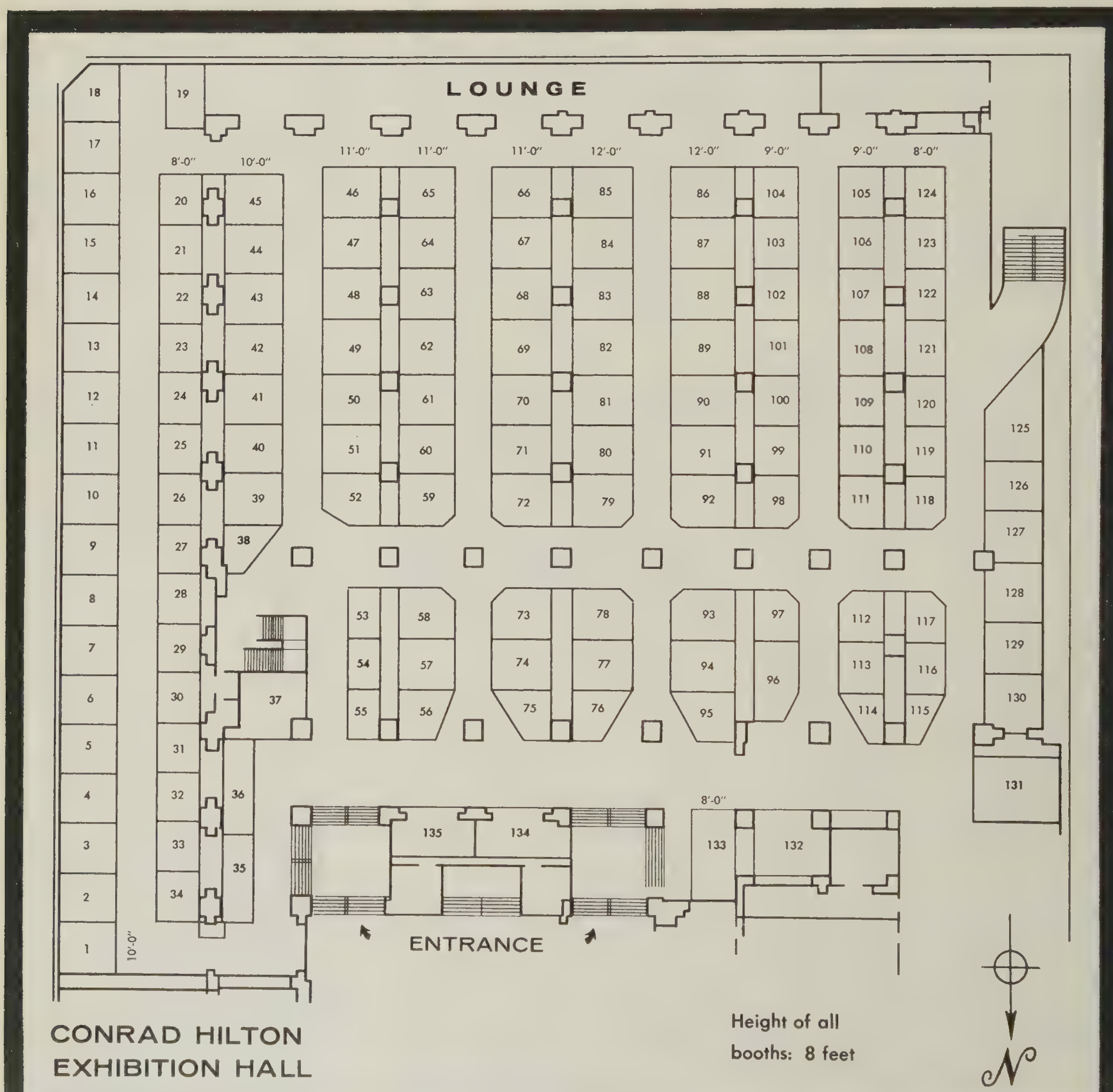
R. R. Titus, President, Synthane Corp., Oaks, Pa.

NATIONAL CONFERENCE ON APPLICATION OF ELECTRICAL INSULATION

Exhibit Hours, Booth Locations, Products and Services Featured

All the exhibits at the Third National Conference on the Application of Electrical Insulation will be located in the Conrad Hilton exhibition hall. They will be open from noon to 9 pm on Monday, December 5; noon to 6 pm on Tuesday, December 6; and noon to 6 pm on Wednesday, December 7.

Tuesday afternoon has been designated Exhibitors' Afternoon, and from noon to 6 pm the conference



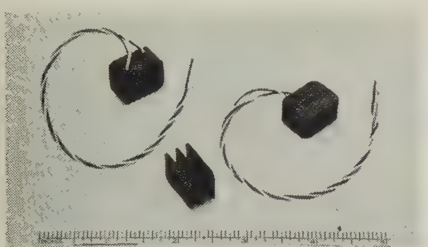
will be devoted exclusively to the exhibits.

Exhibit Locations

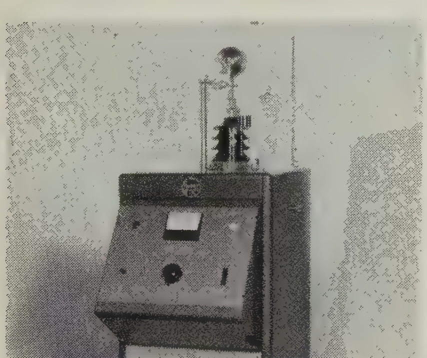
The accompanying diagram and alphabetical listing of exhibitors are your guide to the location of each booth and the types of products or services which will be featured. In the listing, the booth number is given first in bold face type.

•

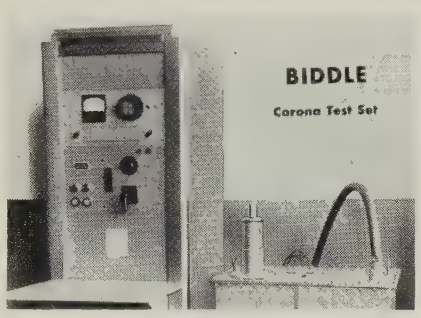
10 *American Institute of Electrical Engineers.*
94 *American-Marietta Co., Seattle.* EMC, a dry, single component epoxy compound for use in molding electronic components. It may be compression or transfer molded



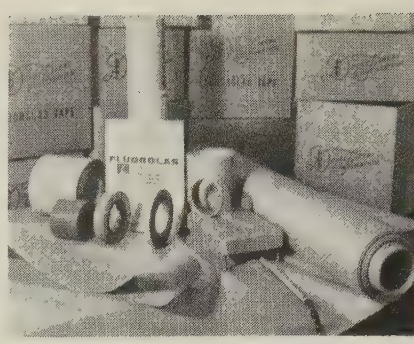
using conventional equipment. Molded parts reportedly have outstanding physical strength, chemical resistance, and electrical properties.
102 *American Society for Testing Materials.*
22, 23, & 24 *Anaconda Wire & Cable Co., New York City.* New cement-coated epoxy magnet wire designed to provide self-supporting coils that retain their shape both cold and hot, even at 200°C. The epoxy coating can be activated by resistance or oven heating, or by solvent.
128 *Associated Research Inc., Chicago.* High voltage a-c insulation materials tester in console type cabinet. It provides 0-50,000 volts at 2 kva capacity for use



in testing insulating materials to ASTM and Mil specifications. Unit is equipped with interlocked test cage, testing jig, and automatic rate-of-voltage rise, with additional manual control.
65 *Atlas Asbestos Co., North Wales, Pa.* New glass-"Dacron" insulating tape for class H requirements combines glass economy with Dacron's superior penetrability, tensile strength, stretch, better abrasion resistance and ability to shrink with heat for a tighter wind. It is soft, fits contours well, and is easy to apply.
19 *Battelle Memorial Institute, Columbus, Ohio.* Infantry field wire with improved flexibility and weather resistance, one of the many examples of ability to call on specialists in many fields to arrive at a satisfactory solution to a wide variety of industrial problems.
28 & 29 *Belden Manufacturing Co., Chicago.* A new and simplified production method for making resistance measurements on ultra fine wire. Equipment of Belden design and explanatory literature will be available.
73 *Bentley-Harris Manufacturing Co., Conshohocken, Pa.* Two new acrylic resin-coated fiber glass sleevings, BH Acryl-A (grade B-A-1) and BH Acryl-C (grade B-C-1). The flexible sleevings reportedly offer a margin of safety well above that required for class B insulation, and the acrylic resin coating, which is compatible with wire enamels and varnishes, will not hydrolize and will not soften or flow when exposed to 232°C for 15 minutes.
56 *James G. Biddle Co., Philadelphia, Pa.* Test equipment designed for measuring corona starting and extinction voltage, appar-



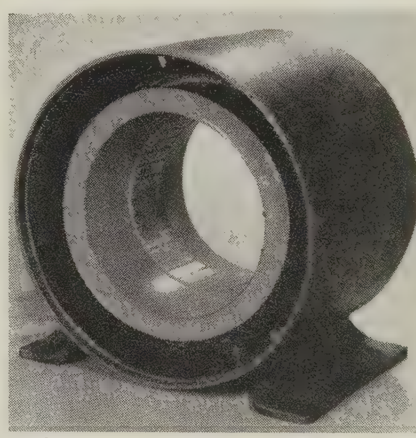
ent corona charge, and relative corona current. The set shown is rated 40 kv, 28 kva, for testing equipment with high terminal capacitance.
51 *Borden Chemical Co., New York City.* Vinyl insulation products.
88 *George C. Borthig Co., Inc., Staten Island, N.Y.* Electrical insulating varnishes.
123 *W. H. Brady Co., Milwaukee, Wisc.* Identification markers.
126 *Carolina Narrow Fabrics Co., Winston-Salem, N.C.* Insulating yarns and woven glass and cotton insulation tapes, webbings, and fabrics.
131 *Chicago Printed String Co., Chicago.* "Res-i-glas" armature banding tape.
44 *Cincinnati Development & Manufacturing Co., Cincinnati.* Glass reinforced polyester resin molded insulation products.
15 *Coast Manufacturing & Supply Co., Livermore, Calif.* "Vec-O-Tex" non-woven cross reinforced fiber glass armature banding tape, said to have ultra high hoop and tensile strength and ultra high cross tensile strength.
80 *Columbia Tape Mills Inc., East Greenville, Pa.* Woven glass fiber insulating tapes.
34 *Continental-Diamond Fibre Corp., Newark, Del.* New punching grades of laminated plastics for use in electrical insulation and a broad line of the latest flexible insulation products.
5 *Dodge Fibers Corp., Hoosick Falls, N.Y.* "Fluorglas" ("Teflon"-glass fabric) in both fabric and pressure-sensitive tape forms. Said to help meet current tendencies towards higher temperatures, miniaturiza-



tion of electrical components, and higher dielectric requirements.

52 *John C. Dolph Co., Monmouth Junction, N.J.* "Dolphon" CB-1054 flexible epoxy resin designed for encapsulating and impregnating transformers, motors, and coils where maximum penetration and flexibility are desired. "Easy to apply" general purpose two-part resin meets MIL-T-27 for class B insulation. It is supplied at extremely low viscosity, cures quickly at moderate temperatures, and has an extended pot life of 4-6 weeks.

59 & 60 *Dow Corning Corp., Midland, Mich.* "Silastic RTV" for the encapsulation of mush-wound motor end turns. Two



methods of application will be featured: One for job lot shops involving the use of forms (photo), and a vacuum impregnation method for original equipment manufacturers.

40, 41, & 42 *E. I. du Pont de Nemours & Company, Inc., Wilmington, Del.* Electrical insulating materials.

133 *Electrical Insulation Conference.*

4 *Electronic Mechanics, Inc., Clifton, N.J.* Mica and glass-mica products.

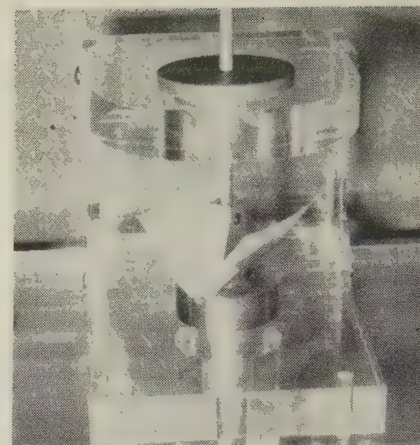
66 *Electro-Technology, New York City.*

54 *Enjay Chemical Co., Elizabeth, N.J.* "Buton" thermosetting hydrocarbon resins that have a dielectric constant of 2.5, dissipation factor of 0.002 at 10^6 cycles and 25°C, and low moisture absorption. They are suggested for use as impregnants, potting and embedding compounds, moldings, laminates, and surface coatings.

57 & 58 *Essex Wire Corp., Magnet Wire Division, Fort Wayne, Ind.* Magnet wires with various insulations.

70 *Exeter Manufacturing Co., Exeter, N.H.* Continuous bias cut, woven fiber glass developed for use as electrical insulation will conform readily to irregular shapes in insulation winding. Special finishes are available for all applications from class A through class H insulations.

35 *Federal Insulation Co., Chicago.* "Epoximat" DM-70 and DM-100 combinations, a



Navy approved class B ground insulation. Rigid quality control, careful lab evaluation, and precise manufacturing specs are featured.

129 *Food Machinery and Chemical Corp., New York City.* Compounds based on "Dapon" diallyl phthalate for molding and Dapon solutions for dip encapsulation. Excellent retention of electrical properties under severe temperature and humidity conditions, extremely low post-mold shrinkage, and resistance to deterioration caused by chemicals, heat, moisture, fungus, etc., are claimed.

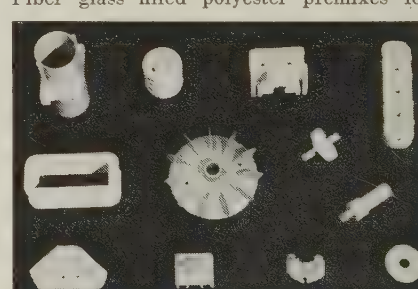
135 *Formica Corp., a subsidiary of American Cyanamid Co., Cincinnati, Ohio.* New flame-retardant grades of industrial laminated plastics for electronic and power-distribution applications.

130 *General Electric Co., Insulating Materials Dept., Schenectady, N.Y.* Electrical insulation products.

124 *General Electric Co., Laminated Products Dept., Coshocton, Ohio.* Insulating laminates.

36 & 37 *General Electric Co., Silicone Products Dept., Waterford, N.Y.* Silicone resin and rubber electrical insulating materials.

103 & 104 *The Glastic Corp., Cleveland.* Fiber glass filled polyester premixes for



molded insulating components in four basic types: flame retardant, non-tracking, high dielectric, and low-cost general purpose.

82 & 89 *J. J. Glenn & Co., Chicago.* Samples of insulation products made by many of the leading electrical insulation manufacturers represented by Glenn in Illinois, Indiana, Western Ohio, Michigan, Wisconsin, Minnesota, Iowa, Missouri, and

Kentucky.

27 *Golden Years Research and Development Center, Ridgemanor, Fla.*

134 *Gudebrod Brothers Silk Co., Inc., New York City.* Lacing cords and tapes.

97 *Hays Manufacturing Co., Reinforced Plastics Division, Erie, Pa.* Glass reinforced polyester resin materials.

98 *Hess, Goldsmith & Co., Inc., Horace Linton Division, New York.* Woven glass fiber insulation products.

132 *Hollingsworth & Vose Co., East Walpole, Mass.* New high purity capacitor insulation paper with low chloride content available from .005″ to .020″, extract conductivity range of less than 5 micromhos, a neutral pH, and high dry as well as high oil saturated dielectric strength.

117 *Hull Corp., Hatboro, Pa.* Resin handling, metering, and dispensing equipment.

67 & 68 *Hysol Corp., Olean, N.Y.* Epoxy insulation materials and systems.

11 *Industrial Instruments Inc., Cedar Grove, N.J.* Model PS Schering bridge for accurate measurement of capacitance and power factor of electrical insulating materials while under high voltage stress. From these measured values and knowing dimensions of the test electrodes and sample, it is possible to calculate dielectric constant and loss factor.

96 *Insulation Manufacturers Corp., Inmanco Division, Chicago.* A class F temperature wedge made from epoxy-glass laminate in curve-formed and square-formed wedge shapes. Wedges combine superior heat resistance, dielectric strength, toughness, and dimensional permanence. Wedges are made in two wall thicknesses, .020″ and .025″, in a range of standard sizes.

90, 91, & 92 *Johns-Manville Corp., New York City.* R-430 "Quinorgo," a heavily saturated silicone, flexible sheet in .010″ nominal thickness for electrical insulating uses. Base sheet combines pure asbestos fiber and woven glass cloth.

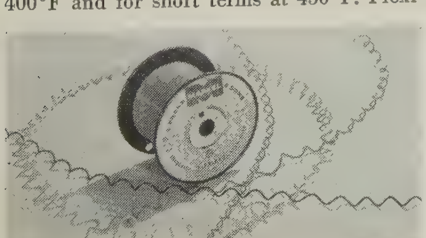
101 *Jordan Manufacturing Co., Des Plaines, Ill.* Extruded insulating tubings and sleevings.

48 *Lake Publishing Corporation, Libertyville, Ill.* Publishers of *Insulation,* the only magazine in the world devoted exclusively to electrical and electronic insulation. Learn about the new *Insulation Directory/Encyclopedia.*

79 *Lenni Products Inc., Lenni Mills, Pa.* Class A, B, and F insulation for electrical apparatus: rolls, sheets, coils, cuffed coils, slot insulators, separators, and wedges.

112 *The Macallen Co. Inc., Newmarket, N.H.* Variety of electrical/electronic insulations made of mica.

81 *L. Frank Markel & Sons, Norristown, Pa.* "Flexlead" silicone rubber insulated lead wire, a high-temperature resistant material said to possess outstanding electrical and thermal characteristics. It is recommended for continuous operation to 400°F and for short terms at 450°F. Flexi-



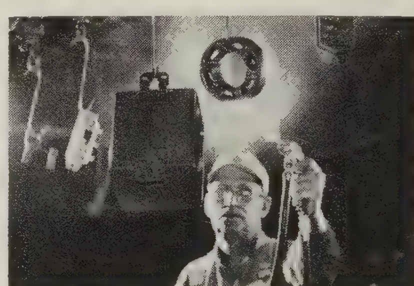
bility, excellent corona resistance, and high resistance to sunlight, weather, and fungi are also reported.

55 *Mesa Plastics Co., Los Angeles.* Diallyl phthalate insulation products.

125 *Milam Electric Mfg. Co., Providence, R.I.* Resin developments which improve the bond strength and the shelf life of "Milamat" class B "Dacron" mat (epoxy bonded

and coated) "Mylar" DM-70 and DM-100 material. Photo shows a stator with the DM-70 as slot liners and phase insulation.

71 & 72 *Minnesota Mining and Manufacturing Co., St. Paul, Minn.* Spray application demonstration of "Scotchcast" brand electrical resin No. XR-5026, a one-part powdered epoxy. XR-5026 can be spray-



coated on motors, stators, rotors, bus bars, transformer cans, computer racks and similar items, providing high cut-through resistance, edge-coating ability to 60-70% of flat surface and a class F (155°C) continuous operating temperature.

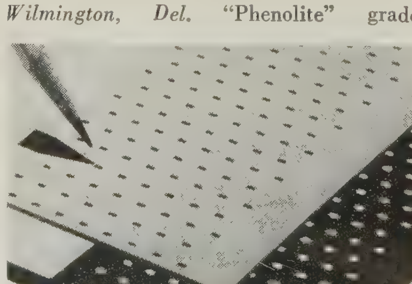
95 *Moxness Products Inc., Racine, Wis.* Triangular, self-adhering "Mox-Tape" silicone rubber insulation and new reinforced self-adhering tape will be featured. A demonstration of tapes with a taping machine will also be included.

20 & 21 *Mycalex Corp. of America, Clifton, N.J.* "Synthamica" 202 synthetic mica paper with a melting temperature of 1365°C and an operating temperature up to 1000°C for use in high temperature transformers, motors, and capacitors.

9 *National Electrical Manufacturers Association.*

122 *National Industrial Service Association.*

38 & 39 *National Vulcanized Fibre Co., Wilmington, Del.* "Phenolite" grade



XXXPC-476, a paper-base phenolic laminate which provides flame retardance with excellent cold punching characteristics, reportedly at nearly half the cost of epoxy-paper laminates. Foil copper-clad laminate also available.

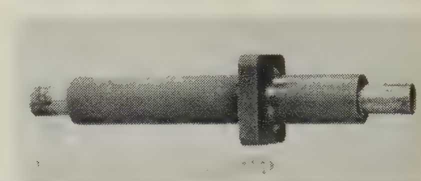
86 *New England Mica Co., Inc., Waltham, Mass.* Manufactured mica products.

46 & 47 *Owens-Corning Fiberglas Corp., New York City.* Glass fiber and glass flake electrical insulation products.

113 *Pennsylvania Fluorocarbon Co. Inc., Philadelphia.* Expanded "Teflon" tubing that shrinks upon application of heat to form a tight fit around irregular shapes and electrical components will be demonstrated. Tubing retains the outstanding electrical, mechanical and chemical properties of Teflon and is available in all popular sizes.

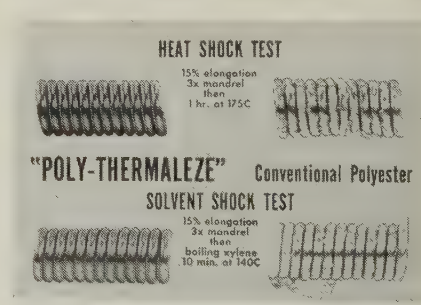
99 *Permacel, New Brunswick, N.J.* "Permacel" EE-6100 high-temperature reflective tape made of a lamination of aluminum foil and glass cloth with a pressure-sensitive silicone adhesive has high tensile strength and good abrasion resistance. It is used on missile and rocket launching site cables.

78 *Permali Inc., Mount Pleasant, Pa.* Custom cast epoxy parts demonstrating the



versatility of cast epoxy in electrical equipment design. Samples will include bushings and stand-off insulators with molded-in conductors.

1, 2, & 3 *Phelps Dodge Copper Products, Corp., Fort Wayne, Ind.* Multipurpose "Poly-Thermaleze" class A, B and F film magnet wire reportedly combines the out-



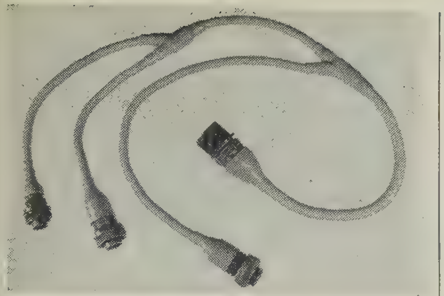
standing properties of six or more conventional film wires. It is said to not sacrifice one property for another—it is completely balanced in all.

105 *Pittsburgh Plate Glass Co., Fiber Glass Division, Pittsburgh.* Glass fiber insulation products.

69 *Polygon Plastic Co., Walkerton, Ind.* Glass reinforced polyester resin rod stock.

7 *H. K. Porter Co., Trenton, N.J.* Insulating tapes.

118 *Rayclad Tubes Inc., Redwood City, Calif.* New harness construction system based upon a complete range of preformed slip-on neoprene and silicone rubber components (boots, transitions, and sleeving) which shrink upon the application of heat at only 250°F. The resulting harness provides complete environmental isolation and insulation, light weight, convenient repair-



ability, speed and reliability in fabrication, and low cost.

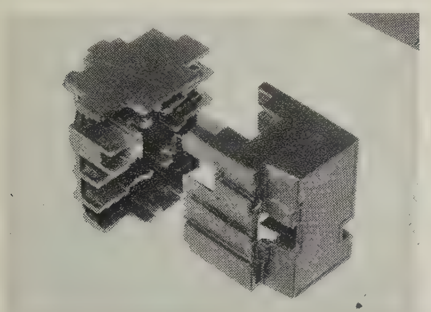
109 *The Richardson Co., Melrose Park, Ill.* "Insurok" T-777, a paper based phenolic laminate rated self-extinguishing with zero inches burning distance and meeting all NEMA XXXP requirements. Available in all standard sheet sizes, it is a hot punch grade with excellent dimensional stability.

74 & 75 *Riegel Paper Corp., New York City.* Specialty electrical papers and boards for various insulation applications in transformers, cables, and motors.

119 *Rohde & Schwarz Sales Co., Inc., Passaic, N.J.* Equipment.

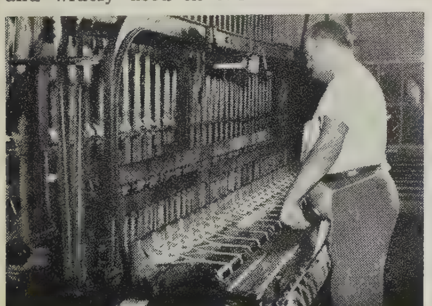
17 *Rome Cable Corp, Rome, N.Y.* Wires and cables.

108 *Rostone Corp., Lafayette, Ind.* Glass and alumina filled polyester bonded "Rosite" 3250 in molded form. A track



free, dimensionally stable, flame resistant, high impact compound for applications in transformers, switchgear, contactors, electronic air cleaning devices, bus systems, and the like.

115 *The Russell Manufacturing Co., Middletown, Conn.* "Rusco" glass insulating tapes woven of continuous filament yarns and widely used in the manufacture and



repair of electrical equipment. High tensile strength, dimensional stability, thinner construction, and resistance to deterioration are features.

116 *St. Regis Paper Co., New York City.* Laminated plastics.

120 *Society of Plastics Engineers.*

106 & 107 *Spaulding Fibre Co. Inc., Tonawanda, N.Y.* "Spauldite" grade XXXP-770, a new laminate combining extremely clean punching at room temperature with fire resistance is available in sheets or fabri-

cated parts. Its electrical properties are excellent.

127 *The Sterling Varnish Co., Sewickley, Pa.* U-372 "Thermo-F" varnish compatible with all types of magnet wire, including the new multipurpose polyester magnet wires. Other features are high bond strength, excellent heat stability at elevated temperatures, superior electrical strength, and excellent moisture, chemical, and oil resistance.

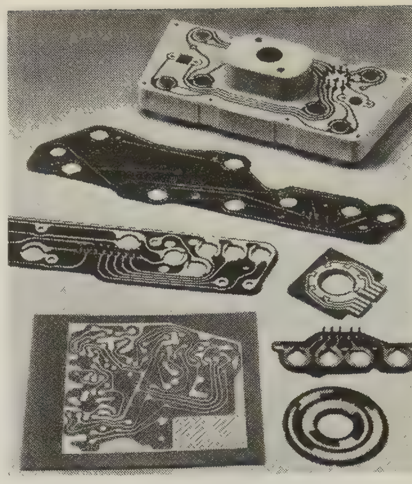
64 *Stranco Products Inc., Chicago.* Electrical insulating materials.

111 *Suflex Corp., Woodside, N.Y.* "Pyrodur" electrical sleeving designed to resist temperatures up to 2300°F in missile and electronics applications. Pyrodur is a new concept in high heat resistant sleeving and is made from "Fiberfrax" ceramic fiber yarn.

83 & 84 *Sun Chemical Corp., Electro-Technical Products Div., Paterson, N.J.* "Acto-Glas" flexible epoxy/polyester impregnated woven glass tapes and cloths possess good dielectric strength in semi-cured stage. They become rigid on curing and reportedly are suitable for 180° C.

93 *Synthane Corp., Oaks, Pa.* Wide range of laminated plastics, including new high-temperature grades AA-HT (asbestos woven fabric), ARF-HT (asbestos mat plastic), and G3-HT (glass fabric plastic).

76 & 77 *Taylor Fibre Co., Norristown, Pa.* "Dytronics" circuits made by die cutting the conductor pattern from metal foil coated on one side with a thermoresponsive adhesive and simultaneously bonding the circuit to the insulating base material under heat and pressure. They are mass-



produced for a wide variety of applications.

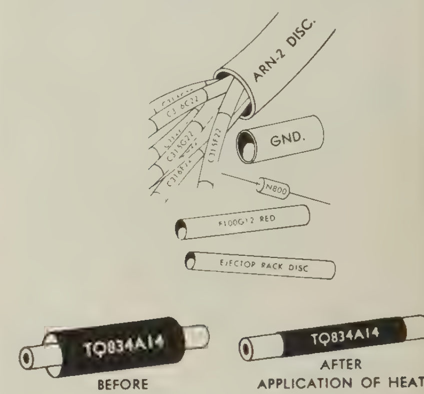
32 & 33 *Technical Tape Corp., New Rochelle, N.Y.* High performance glass cloth tape (X6023) for applications requiring

maximum adhesion and/or extreme flexibility. The tape has a silicone-treated glassine liner.

49 & 50 *Union Carbide Corp., Silicones Division, New York City.* Silicone resin and rubber electrical insulation materials.

45 *Varflex Sales Co. Inc., Rome, N.Y.* Class H insulating sleeving with silicone resin or silicone rubber as the impregnant in thinner wall constructions and long length coils.

87 *Western Lithograph Co., Los Angeles.* Pre-printed "Shur-Code" insulation sleev-



ing that is slipped over wires, cables, and harnesses for permanent identification. Available in a complete range of standard and special materials.

61 & 62 *Westinghouse Electric Corp., Pittsburgh.* Electrical insulating materials.

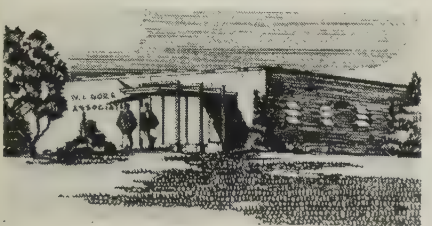
26 *J. B. Whitehead Award.*

63 *The Zippertubing Co., Los Angeles.* Zippered tubing for wire and cable harnessing.

Industry News

Production of vinyl resins and compounds has begun at the new Long Beach, Cal., plant of *B. F. Goodrich Chemical Co.*

Construction has begun on a new research, development, and manufacturing facility in Newark, Del., for *W.*



L. Gore & Associates Inc., manufacturer of "Teflon" insulated wire and cable.

Empire Flight Components Inc., Bellmore, L.I., N.Y., has been merged into *Instrument Systems Corp.*, College Point, L.I., N.Y. EFC continues operations as a division of ISC.

Synthane Corp., Oaks, Pa., has installed complete facilities for fabricating industrial laminated plastics in its plant in Glendale, Calif.

AMP, Inc., Harrisburg, Pa., manufacturer of electronic components and electrical terminations, has won a consent decree in a suit against Burmac Electronics Co. Inc., under which Burmac is ordered to return all AMP drawings, prints, specifications, and other physical properties it has in its possession.

A new 400-ton capacity molding press for producing laminated sheets

up to 4′ x 8′ is shown being installed at *Hays Manufacturing Co.*, Erie, Pa.

D & H Distributing Co., Harrisburg, Pa., is now a member of the national "Fabricator of Industrial Formica" organization of the *Formica Corp.*, a subsidiary of *American Cyanamid Co.*, Cincinnati, Ohio.

Giannini Scientific Corp., New York City, has completed its third acquisition this year, the latest being *Micro-Balancing Inc.*, Garden City Park, Long Island, N. Y., manufacturer of dynamic balancing machines and photocell control devices for lights.

The *H. R. Davies Sales and Engineering Co.*, New Orleans, has been appointed to represent the *Despatch Oven Co.*, Minneapolis, manufacturer of industrial ovens, in the lower Mississippi and Louisiana area.

Minnesota Mining & Manufacturing Co., St. Paul, Minn., has reported sales of $403,146,898 for the first nine months, with net income of $50,134,365 equal to $.98 per share. This compares with sales of $363,-332,469, and income of $45,698,317, or $.89 per share, for the same period of 1959.

Net income equal to $2.36 per share of common stock for the nine months ended Sept. 30 has been reported by *Hercules Powder Co.*, Wilmington, Del. Earnings in the period were equal to $2.07 per share of common stock.

Connecticut Hard Rubber Co., New Haven, Conn., manufacturer of silicone rubber parts, has formed an Electrical Products Dept., with an electrical marketing group directly servicing OEM users in the fields of rotating equipment and wire and cable. Also, silicone rubber electrical tape manufacturing facilities have been expanded.

Temperature Engineering Corp. has begun construction on a 35,000 sq ft plant in Riverton, N.J. When completed in January, it will almost triple the firm's present facilities for manufacturing constant temperature processing equipment.

The Keystone Electronics Co. Inc., Newark, N.J., manufacturer of crystal products, has purchased the Lawrence Manufacturing Corp., Belleville, N.J., manufacturer of ultrasonic cleaning equipment, and will operate it as a subsidiary.

New Products

For further information on these products print the item number on the Reader Service Inquiry Card on the back cover. Fill out and mail the card —no postage is required. Insulation *will immediately forward your inquiry to the manufacturers concerned so that they can send you more information promptly.*

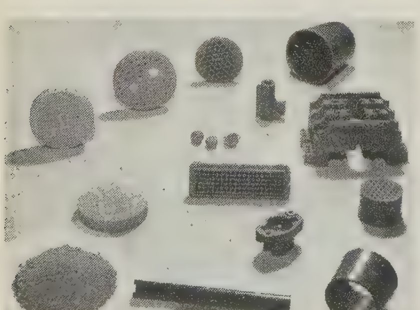
Resistor Composition for Use on Ceramic Dielectric Bases

A new line of resistor compositions offer varied resistance values to provide greater flexibility in miniaturized circuitry. The compositions are available in three resistance values (500; 3,500; 10,000 ohms/sq/mil thick film) which can be blended to obtain intermediate values. Applied to ceramic dielectric bases by ordinary dip, brush, or stencil screen techniques, the composition is then fired in a normal atmosphere to obtain a durable surface. Electrical properties of the resistors are reproducible and tests show that fired printed patterns and coated rods have abrasion and impact resistance similar to fired silver coatings. Resistance values are said to exhibit excellent stability under varying conditions of humidity, temperature, overload, and voltage. Screen printing and dipping compositions are being sold initially in each of the three resistance values at $8 a Troy oz. E. I. du Pont de Nemours & Co., Ceramic Products Div., Wilmington 99, Del.

Print No. Ins. 101 on Reader Service Card

Continuous Service at 700°F For New Molded Silicone Parts

A specially-compounded, mineral-filled silicone molding compound is said to provide parts with outstanding dimensional stability and thermal shock resistance over a temperature range of —67 to +700°F. Compound M-6-4156 molded parts reportedly demonstrate high arc resistance (over 400 sec) and dissipation factors as low as 0.002 at 10^6 cps. Easily molded using conventional compression or transfer molding equipment and techniques, the properties of M-6-4156 reportedly suggest its suitability for connector plugs, fuses and fuse holders, contactors, coil forms, arc barriers, relay parts, tube sockets, tube bases, switch parts, terminal parts, and the replacement of ceramic parts. Complimentary evaluation sample and complete technical details may be obtained. New Products Dept., Dow Corning Corp., Midland, Mich.



Print No. Ins. 102 on Reader Service Card

Flexible Glass Flake/ Glass Cloth Composite

Flexible composite FG-54 combines the physical properties of glass cloth and the properties of "Fiberglas" flake sheet. A network of overlapping glass flakes in the base sheet provides a continuous dielectric barrier. When subjected to high temperatures, FG-54 reportedly demonstrates good thermal conductivity and dimensional stability, and maintains excellent dielectric properties. Good impregnation characteristics, excellent cut-through resistance, and high moisture resistance are claimed. Owens-Corning Fiberglas Corp., 717 Fifth Ave., New York City.

Print No. Ins. 103 on Reader Service Card

Self-Extinguishing Phenolic Laminate for Printed Circuits

A new phenolic laminate reportedly combines low cost with excellent self-extinguishing and electronic insulating properties. The new material, 'Textolite" 11586, is described as having outstanding self-extinguishing properties: flame out in less than 5 sec. High insulation resistance in humidity, high dielectric reliability, excellent impact resistance, and easy machinability are also claimed. The NEMA grade XXXP laminate is stated to be 33-40% lower in price than comparative epoxy paper base materials and to have been specifically designed for electronic applications subject to UL labeling. Available in both standard and copper-clad sheets for printed circuits for application in computers, television, radio, and other electronic components. The new laminate is also said to punch cleanly at temperatures from 80°F to 130°F without cracking or undercutting. It is translucent to facilitate circuit registration. General Electric Co., Laminated Products Dept., Coshocton, Ohio.

Print No. Ins. 104 on Reader Service Card

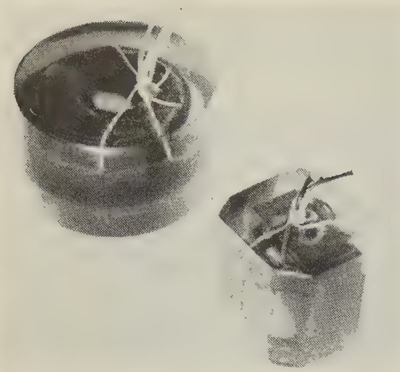
High Density Polyethylene with Improved Processability

A new type of high-density polyethylene combines improved durability with processability. "Ameripol" polyethylene reportedly has environmental stress cracking resistance (SCR) and temperature embrittlement resistance, while maintaining the processing ease of conventional high-density polyethylene. These characteristics, combined with other high-density properties, are said to make it exceptionally suitable for insulation for wire and cable and for extruded pipe. Goodrich-Gulf Chemicals Inc., East Ohio Bldg., Cleveland 14, Ohio.

Print No. Ins. 105 on Reader Service Card

Epoxy Casting Powder for Protecting Electrical/Electronic Components

"Maraset" epoxy casting powder #135E is a single-component resin which is liquefied at 110°C, and then poured over the part to be protected in a mold which has been lubricated and preheated to 110°C. After a 12-hr oven cure at 125°C, the completely hardened encapsulation is easily removed from the mold. The semi-flexible, unfilled epoxy composition has sufficient clarity to show the embedded part. Meeting MIL-T-27A, resin 135E permits continuous opera-

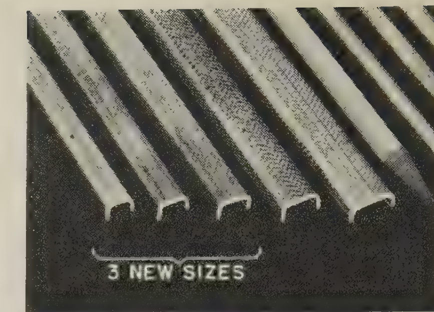


tion in the H temperature class. Adhering firmly to the encapsulated part, it is also said to impart high impact, tensile, and dielectric strengths, along with resistance to such environmental hazards as exposure to water and chemicals. Marblette Corp., 37-31 Thirtieth St., Long Island City 1, N.Y.

Print No. Ins. 106 on Reader Service Card

Three New Sizes of U-Wedges Molded Of Glass Reinforced Polyester

Three new sizes have been added to a line of U-shaped stator wedges for class B and H electric motors. The additions have widths of 5/16",



11/32", and 3/8". They bring to 11 the number of U-wedges available, in widths of 3/16" through ½" and standard lengths of 36". Special one-piece molded construction of polyester reinforced with woven fiber glass is said to provide higher strength and easier driving than wood or fibre wedges, and space-conserving design allows greater coil cross-section. Dielectric strength is 3,000 minimum. Engineering data, prices, and samples are available. The Glastic Corp., 4321 Glenridge Rd., Cleveland 21, Ohio.

Print No. Ins. 107 on Reader Service Card

Liquid Epoxy for Impregnating

A new, two-component, liquid epoxy insulation system is designed to produce void-free impregnation of fine wire, interleaved high voltage coils. It may also be used as the compatible encapsulating casting material. Outstanding electrical properties, resistance to thermal and mechanical shock, and economical use are claimed. Bulletin E-309 available. Electrical Insulation Div., Hysol Corp., Olean, N.Y.

Print No. Ins. 108 on Reader Service Card

Wet Process Alumina Ceramic for Large and Complex Shapes

Large and complex designs in alumina ceramic parts are now available up to 12" x 20" with depth in proportion in production runs. Pictured is one section on an electrical insulating support bracket. The "Diamonite" materials used contain up to 97% aluminum oxide and are said to be capable of withstanding repeated heating to over 1,000°C with air

quenching without loss of strength. High alumina ceramic boards for use as printed circuit bases are one of the promising applications. Diamonite is reported to be successfully withstanding a temperature of approximately 6,000°C in a switching operation with a switching interval of one microsecond. The material is claimed to be excellent for any usage where lowest dielectric loss, high heat resistance, and maximum resistance to environmental factors such as corrosion. wear, and mechanical shock are needed. Diamonite Products Mfg. Co., Shreve, Ohio.
Print No. Ins. 109 on Reader Service Card

Silicone Glass Laminate For Many Class H Uses

A silicone-glass cloth laminate said to have excellent electrical properties, impact strength almost three times that of NEMA grade G-7 standards, and low moisture absorption is designated as "Lamicoid" grade No. 4053-3. It reportedly is suitable for a wide variety of class H equipment. The new heat-resistant laminate is claimed to withstand continuous exposure to 200°C (photo). Its arc resistance is 180 secs, and its low moisture absorption—typically 1/6 that of NEMA G-7 standards—makes it suitable for use as an insulator under

high humidity conditions. No. 4053-3 meets NEMA G-7 and MIL-P-997B. Mica Insulator Div., Minnesota Mining and Manufacturing Co., Schenectady 1, N.Y.
Print No. Ins. 110 on Reader Service Card

Dielectric Coating Resists 2000°F

A 500 vpm dielectric strength and high temperature thermal protection reportedly are provided by an insulation coating composed of both organic and inorganic compounds. Applied by conventional spray equipment to a thickness of 17-20 mils in one coat, and given graduated thermal curing, the PT-209 material is said to have resisted 6000°F for 15 seconds before carbonizing, and 2000°F continuously with a butane flame. Thermal conductivity is recorded at Kc-600°F—1.8, (BTU/hr/ft^2/° F/in) and Kc - 900°F — 2.2. Other properties claimed include excellent adhesion, good flexibility, thermal shock resistance, and resistance to abrasion, oil, and water. Data sheets available. Product Techniques Inc., 511 East 87th Place, Los Angeles 3.
Print No. Ins. 111 on Reader Service Card

Low Viscosity RTV Silicone Rubber For Potting, Impregnating, Coating

A new room temperature vulcanizing silicone rubber, designated as

RTV-11, is said to offer a lower viscosity than has ever before been available in any silicone rubber compound. The strong, resilient rubber is stated to possess excellent resistance to temperature extremes, ozone, weathering, and aging. It contains no solvent and has a viscosity in the 120 poise range. Easily pourable in and around irregularly shaped configurations, it is especially suited for potting, encapsulating, and impregnating of electrical and electronic components. One suggested application is use as a protective conformal coating over printed circuit boards. Silicone Products Dept., General Electric Co., Waterford, N.Y.
Print No. Ins. 112 on Reader Service Card

Glass-Asbestos-Silicone Paper with Dielectric Strength of 400 V/M

Style #7527 is a silicone impregnated combination of glass and a highly purified, long-fibered asbestos paper which has a fine, smooth, and uniform texture. Available in .007" and .010" gauges, the composite weighs 56 lbs/100 sq yds in .010" gauge. The paper base sheet is a composition of 85% asbestos and 15% glass fiber. Tensile per 1" of width is 60 lbs lengthwise, and 30-40 lbs crosswise, depending on the gauge. Average tear strength is over 1,000 grams in either machine or cross-machine direction. Average dielectric strength is 400 v/m. Asbestos Textile Div., Raybestos-Manhattan Inc., Manheim. Pa.
Print No. Ins. 113 on Reader Service Card

Light Weight Epoxy Embedding Resin With Good Heat Dissipation

Good heat dissipating qualities are featured in a new light weight epoxy resin, "Randac" system G-07, designed for embedding heat generating electronic assemblies used in mobile or aircraft equipment. The weight-saving system reportedly displays good thermal conductivity for a low density product (1.5 x 10^{-4} cal/sec/cm^2/°C/cm). Because it is prefoamed, application conditions are not critical, with little exotherm when poured and set at room temperature. Complete specification, application, and price information available. Mitchell Rand Mfg. Corp., 51 Murray St., New York 7.
Print No. Ins. 114 on Reader Service Card

Clad Laminate with Improved Impact Resistance and Flexural Strength

A new reinforced copper-clad plastic laminate, designated XXXP-36RE, is a paper-base grade said to have superior impact resistance and flexural strength. The material is supplied in 1/32" to ¼" thicknesses, with semi-gloss finish. Typical properties reported are: Izod impact—LW, 2.50 ft lbs/in notch; CW 1.10 ft lbs/in notch. Flexural strength—LW, 24,000 psi; CW, 17,000 psi. Formica Corp., Subsidiary of American Cyanamid Co., 4614 Spring Grove Ave., Cincinnati 32, Ohio.
Print No. Ins. 115 on Reader Service Card

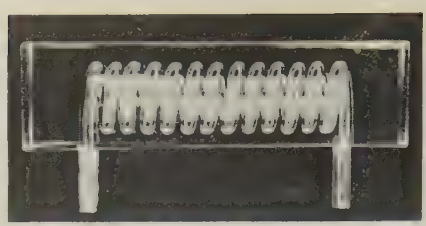
Glass Reinforced Alkyd Compounds With Arc and Flame Resistance

A new line of glass reinforced alkyd

molding compounds for use in the electrical field reportedly has outstanding properties with respect to track-resistance, arc-suppression, and flame resistance. Glaskyd Incorporated, Perrysburg, Ohio.
Print No. Ins. 116 on Reader Service Card

Flame and Heat-Resistant Coatings Bonded to Plastics

Work in the missile, rocket, and related fields reportedly has demonstrated that a group of flame and heat-resistant coatings can be bonded to and are compatible with sheets, tubes,



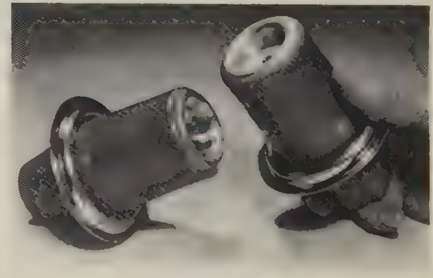
and molded shapes of many grades of industrial and high temperature plastics. The intumescent (swelling or enlarging with heat) coatings which have been applied to plastics are now being used to protect electrical components during missile launchings. The coatings are put on by ordinary brush or spray techniques and are air-drying at room temperature. No heating is necessary to complete the bonding process. Technical Service Dept., Continental-Diamond Fibre Corp., Newark 17, Del.
Print No. Ins. 117 on Reader Service Card

Electronic Components Molded And Extruded of "Teflon" FEP

A wide variety of electronic components molded and extruded of Teflon FEP fluorocarbon resin can be produced in intricate shapes with sections as thin as .020″-.030″. As with other Teflon resins, FEP reportedly is virtually immune to chemical attack. has excellent electrical insulating properties, anti-stick and frictional characteristics, and will not absorb moisture. It has a continuous service range from —395°F to +400°F. Garlock Electronic Products, Camden 1, N.J.
Print No. Ins. 118 on Reader Service Card

Epoxy Hermetic-Seal Bushings

Designed for solder-in installation into hermetically sealed metal equipment enclosures. the new model M-1003 hermetic-seal feed-through bushings are constructed of solid cast-epoxy resin. Having no internal voids to be filled with oil, they can be mounted in any position. Internal stress-control structure reportedly gives uniform field distribution over



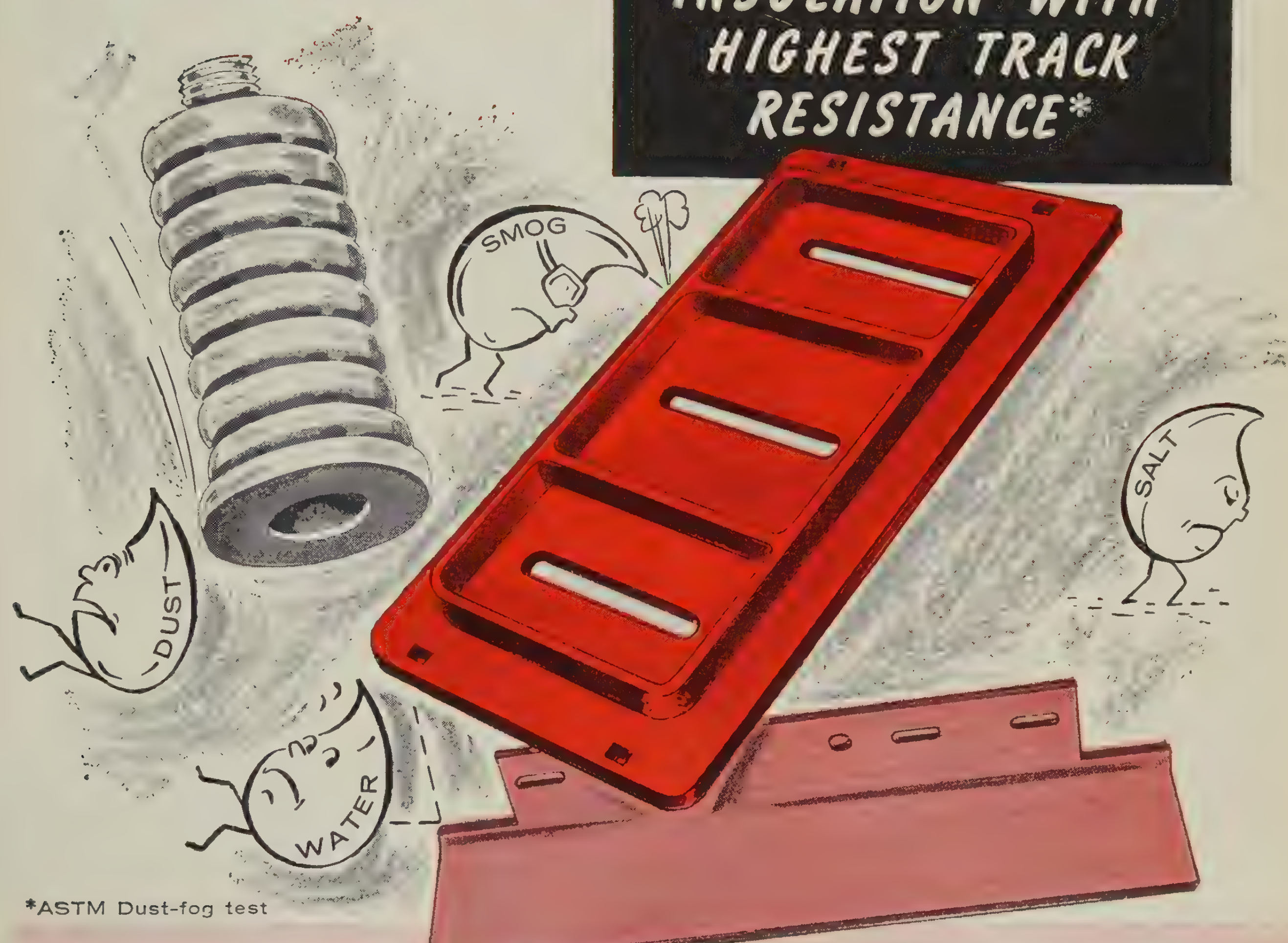
the epoxy surface and makes the model M-1003 capable of corona-free operation at 40 kv, with peak pulse operating level of more than 70 kv for air-to-oil, or 140 kv oil-to-oil, operation. Flashover is 65 kv positive d-c. Epoxy construction also contributes a thermal-shock resistance range from —60 to +175°F. Over-all length is 5″; weight is 16 oz. Components for Research Inc., 979 Commercial St., Palo Alto, Calif.
Print No. Ins. 119 on Reader Service Card

Insulating and Sealing Grommet

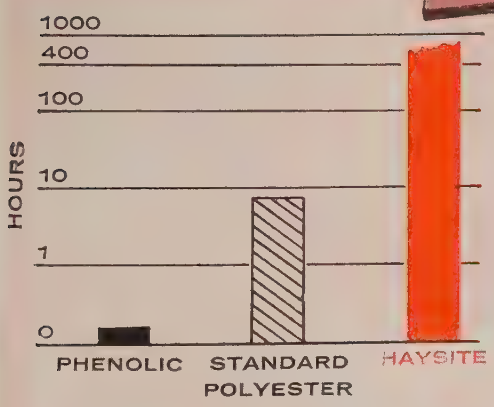
The new "ARco" sealing grommet

HAYSITE® 136AT ETR-FR

INSULATION WITH HIGHEST TRACK RESISTANCE*



*ASTM Dust-fog test



Haysite insulates 2000 times better than standard phenolics under contaminated industrial conditions. Self extinguishing and tough, these reinforced fiber glass alumina polyesters are available as a premix or a laminate. Priced competitively, Haysite offers tested proof of fault protection. Other Haysite laminates and premix moldings are available to meet specific application requirements. For all the facts, write for Technical Bulletin 136AT for premix or 134 ETR-FR on laminates.

HAYSITE

REINFORCED PLASTICS DIVISION

HAYS MANUFACTURING COMPANY

815 WEST 12TH STREET • ERIE, PENNSYLVANIA

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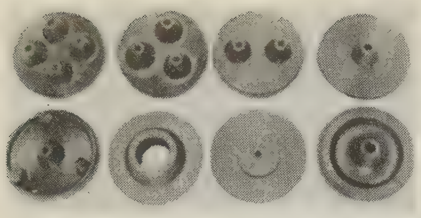


is a cellular sponge plastisol which can be molded to suit any required situation, in any size, shape, or dimension. Its design, with spring steel retaining tabs, is said to insure positive seal between grommet membrane and sheet metal. It reportedly does not deteriorate in heat or cold and lends itself to any specified shape for insulation around wires, conduit tubes, or cable. Corrosion and electrical insulation properties are claimed. It is also stated to be non-absorbative and to prevent chafing, cutting, shorting, and rattling. Readily removed and replaced, it provides protection for ragged edges of holes. Available in various elastomeric insulating materials. Automotive Rubber Co., 12550 Beech Rd., Detroit 39.

Print No. Ins. 120 on Reader Service Card

Uniform Epoxy Coating of Components

A new technique is stated to allow a uniform coating of epoxy insulation, free from pin-holes, to be applied to rotor and stator stacks with skewed or straight slots, transformer cores, condensers, and other components used in the electronic field. The coatings are said to be hard, glossy, moisture-resistant, and resistant to cut-through. Complete edge coverage, coating thickness as low as .003″, dielectric strength at 25°C of 15,500 v a-c instantaneously applied to a 10 mil coating, and ability to withstand 170°C for 1000 hrs are claimed. Spatco Mfg. Co. Inc., 45-31 Davis St., Long Island City 1, N.Y.

Print No. Ins. 121 on Reader Service Card

Fluorocarbon Film Cementable With Common Adhesives

One side of a new Teflon FEP-fluorocarbon film is cementable with common adhesives. Prior to development of the new film, the only way to provide a surface receptive to adhesives was by a patented treatment with alkali metals in organic media. The only other method of laminating it to another material was by heat-sealing or heat-bonding, which ruled out use of all substrates sensitive to extreme heat. Development work to date indicates that the new film type can be anchored with many standard adhesives to a variety of materials. It may also be used, without adhesives, to provide a printable or "pottable" surface on spiral-wrapped, heat-sealed jacketing for wire and cable. The Teflon FEP-fluorocarbon film shares all the properties of the older TFE-fluorocarbon films at temperatures up to 400°F. In addition, the film is stated to be heat-sealable and heat-bondable to itself and many other materials. E. I. du Pont de Nemours & Co. Inc., Film Dept., Wilmington, Del.

Print No. Ins. 122 on Reader Service Card

Liquid Epoxy Casting System

A new, two-component, liquid epoxy casting system for insulating high performance electrical-electronic equipment was developed to meet the requirements of MIL-I-16923C, Types B, C, and D. It is said to be outstanding in its balanced electrical, thermal, and physical properties. Bulletin E-291 available. Electrical Insulation Div., Hysol Corp., Olean, N.Y.

Print No. Ins. 123 on Reader Service Card

High-Strength, Solvent-Free, Contact-Pressure Epoxy Adhesive

"Maraset" resin 533A is a two-component, contact-pressure epoxy adhesive that can be cured at room temperature to provide high bond strength. The resin is furnished as a solvent-free, non-volatile, medium-thick paste with a 2-hr pot life. It meets MIL-A-8623, Type II, specification for the aircraft industry. The new adhesive can be used to bond metals, wood, glass, rubber, and plastics. It is said to have demonstrated ability to create a durable bond that will not delaminate even under heavy duty. Properties listed include low shrinkage, resistance to mechanical and thermal shock, high creep resistance under constant stress, low moisture absorption, and good resistance to water, chemicals, oils, solvents, and aromatic fuels. Marblette Corp.. 37-31 Thirtieth St., Long Island City 1. N.Y.

Print No. Ins. 125 on Reader Service Card

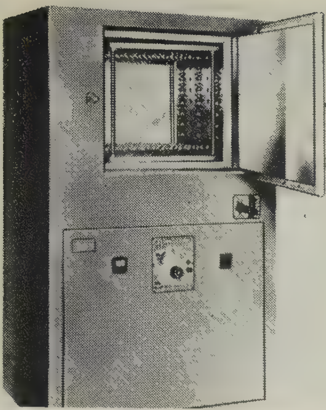
Extruded Polycarbonate Tubing, Strips, Small Rods, and Profiles

Polycarbonate tubing is now being extruded from "Lexan" material in diameters over 1″ and with wall thicknesses over .100″. Tubing diameters which can be ordered range from .040″ to 1½″ and wall thicknesses from .015″ to .125″. In addition, strips, small rods, and profiles can also be extruded. Anchor Plastics Co. Inc., 36-36 36th St., Long Island City 6, N.Y.

Print No. Ins. 126 on Reader Service Card

Ovens for Accelerated Aging

Mechanical convection, horizontal airflow aging ovens with saturable power reactor control and built-in range-lock overtemperature protection are said to be ideal for accelerated aging at controlled temperatures of rubber, plastics, insulations, varnishes, etc. Temperature range is 35°C to 180°C. Straight-line control is derived from a control system without contacts, switches, moving parts, or auxiliary mechanisms to wear.



burn, or arc. Four standard sizes available with ID's from 14″ × 14″ × 14″ to 38″ × 20″ × 25″. Removable sample racks permit use as a standard utility mechanical convection oven. Simultaneous suspension of 49, 110, 168, or 240 samples are possible. Bulletin 1960 available. Blue M Electric Co., 138th and Chatham St., Blue Island, Ill.

Print No. Ins. 127 on Reader Service Card

Multirange Instruments

Typical specifications claimed for Unigor 3 measuring instrument are 25,000 ohms per volt d-c and 2,000 ohms per volt a-c, maintaining the high accuracies of 1.0% on d-c and 1.5% a-c; current measurements of 100 microamps to 5 amps d-c and

500 microamps to 5 amps a-c; voltage measurements of 100 millivolts to 5,000 volts d-c and 500 millivolts to 5,000 volts a-c; resistances up to 50 megohms; capacitance from 100 micromicrofarad; full automatic overload protections; 48 ranges in all, including output from —34 db to +56 db. All Unigor instruments are priced at $98.50 fob Hempstead. Physics Research Laboratories, Hempstead, N. Y.

Print No. Ins. 128 on Reader Service Card

New Literature

All catalogs, bulletins, and other literature or sample cards described are available free of charge. To obtain your free copies, just print the item number on the Reader Service Card on the back cover. Fill out and mail the card—no postage is required. Insulation *immediately forwards your requests to the companies concerned so that literature can be sent to you promptly.*

Epoxy Resin Data Sheet and Application Brochure

New brochure describes and illustrates the six steps in a "brush-on" method of encapsulating stators with a thixotropic liquid epoxy. The data sheet lists electrical and other properties of the resin and also discusses application. 4 pages. John C. Dolph Co., Monmouth Junction, N.J.

Print No. Ins. 201 on Reader Service Card

Bulletin and Sample of Flexible Plastic Coated Fiber Glass Sleeving

New bulletin describes a flexible class B sleeving with a fiber glass base and a plastic coating. Electrical and thermal properties and other characteristics and specifications are given, and a sample is included. 4 pages. L. Frank Markel & Sons, P. O. Box 752, Norristown, Pa.

Print No. Ins. 202 on Reader Service Card

Brochure on Encapsulating Stators with Silicone Rubber

Illustrated bulletin CDS-254 lists the advantages of a RTV (room temperature vulcanizing) silicone rubber system and describes in detail a no-mold method of stator encapsulation for motors subjected to rigorous operating conditions. It outlines the method of encapsulation and preparation of materials and equipment. 4 pages. General Electric Co., Silicone Products Dept., Waterford, N.Y.

Print No. Ins. 203 on Reader Service Card

Bulletin on Nylon Cable Ties and Straps

Nylon cable ties and straps for securing and identifying wiring bundles are described in new bulletin TR3. This bulletin shows applications using Ty-Rap cable ties and straps, lists the complete line, and gives installation instructions. 4 pages. The Thomas & Betts Co., 36 Butler St., Elizabeth, N.J.

Print No. Ins. 204 on Reader Service Card

Booklet on Epoxy Impregnation

A new booklet discusses epoxy impregnating resin and its advantages. The equipment and refinements necessary to process it and methods of application are covered. 4 pages. J. P. Devine Mfg. Co., 49th St. & A.V.R.R., Pittsburgh, Pa.

Print No. Ins. 205 on Reader Service Card

Comparison Chart of Insulating Materials Properties

A quick informational reference for engineers in search of high-temperature insulation materials for electrical, electronic, avionic, and nuclear applications, the revised Compara Chart details the commonly-used plastic and ceramic insulating materials, including some ceramoplastics and glass-bonded mica. The leaflet also lists Fahrenheit temperature limits for 88 materials and contains a table of thermal expansion coefficients of 57 widely used insert metals and insulating materials. 4 pages. Mycalex Corp. of America, 125 Clifton Blvd., Clifton, N.J.

Print No. Ins. 206 on Reader Service Card

Adhesives Selector Chart

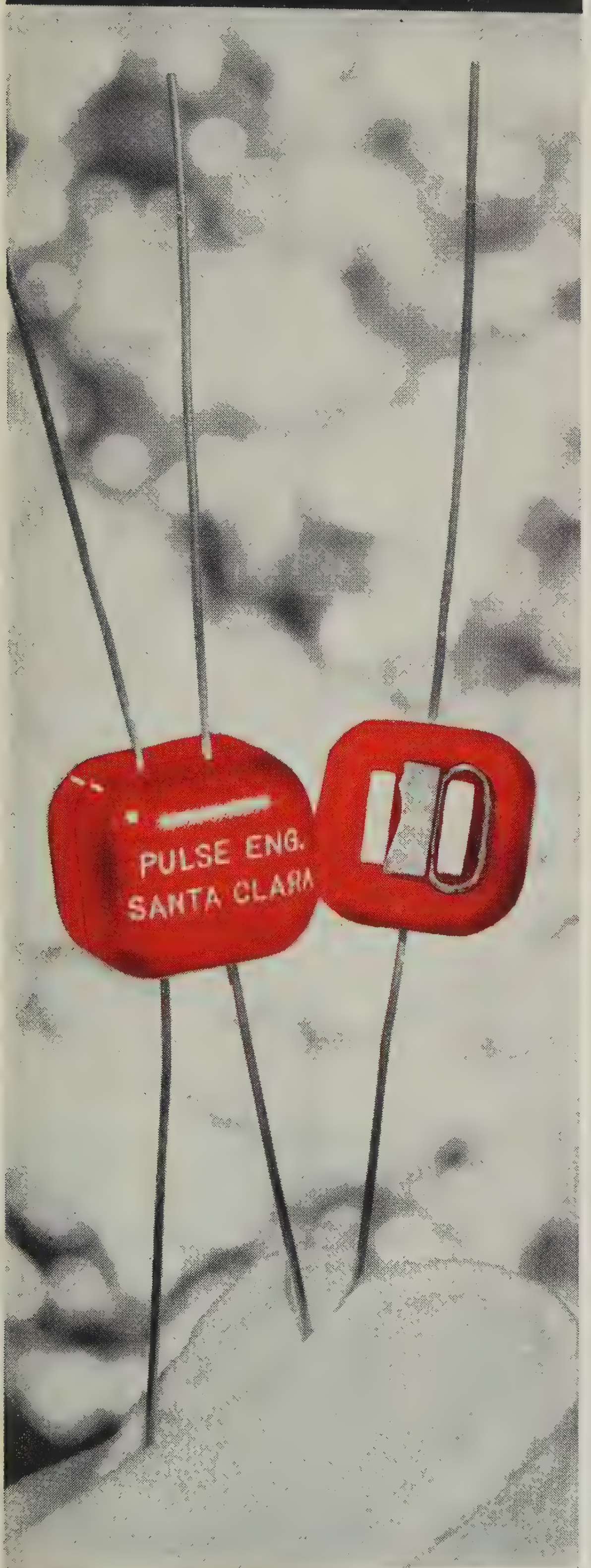
New selector chart shows the outstanding properties of several adhesives and hardeners and their tensile shear strengths at different temperatures and in several fuels. Also, the operating temperature range, Izod impact, coefficient of thermal expansion, and numerous other criteria are indicated. Adhesives Department, Hysol Corp., Olean, N.Y.

Print No. Ins. 207 on Reader Service Card

Urethane Foam Fact File And Progress Report

New brochure serves as a pictorial progress report and as a designer's fact file on industrial and commercial

American-Marietta's EMC® BOOSTS PRODUCTION OVER 420%



Greater product uniformity... better part performance... 70% less labor–with American-Marietta's new EMC epoxy compounds, says leading magnetic component manufacturer.

Previous methods involved costly hand application of layers of resin material. New EMC transfer molding process guarantees a moisture-proof, uniform high density epoxy package. New product appearance is graphically compared by EMC molded part shown at center right with former version.

Again EMC clearly proves its superiority under rigid MIL Spec test requirements. Improved resistance to moisture and temperature cycling as well as standardized part size and shape are some of the important reasons why Pulse Engineering of Santa Clara, California, switched to EMC transfer molding. As a result, output of miniature pulse transformers jumped from 130 to 550 parts per worker per shift, a gain of over 420%, relates Hugh B. Fleming, Pulse President, who intends further expansion utilizing the versatile, reliable properties of EMC.

Unique, Versatile Plastic Materials for advanced Design and Product Development

EMC Epoxy Molding Compounds are available with built-in mold release and optional non-burning properties in a wide choice of fillers, colors and reinforcements readily adaptable to your production requirements.

Single component dry granular systems, they offer an exceptional balance of electrical, chemical and physical properties. Long range research and extensive military and industrial evaluation continue to demonstrate the reliability and design compatability of American-Marietta's new EMC systems.

- *Low pressure transfer and compression molding*
- *Self-releasing No outgassing*
- *One component dry granular system*
- *Outstanding balance of properties*
- *Low moisture absorption*

Like to see how EMC can play an important part in your next project? Write the nearest American-Marietta Technical-Sales office listed below citing your applications.

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Print Ins. 401 on Reader Service Card

applications for urethane foams. Property and performance data relating to such fields of use as insulation, missile components, void-filling and potting compounds, are well defined for practical reference at the material specifying level. 26 pages. Mobay Chemical Co., Penn Lincoln Parkway West, Pittsburgh 5, Pa.

Print No. Ins. 208 on Reader Service Card

Bulletin on Arc Resistant, Flame Retardant Glass-Polyester

New bulletin 6025 describes a special formulation of polyester resins reinforced with glass and inorganic materials which can be laminated, cast, or molded. Properties and wide variety of applications are illustrated and discussed. Arc resistance and flame retardance are covered. 4 pages. Federal Pacific Electric Co., 50 Paris St., Newark 1, N.J.

Print No. Ins. 209 on Reader Service Card

Sticking Compounds Data Sheet

New information sheet describes two sticking compounds, MC-715 and MC-738, for holding down the ends of paper, tape, or wire during the winding of coils, and for cementing various materials together, such as cotton, linen, glass, varnished tape, and laminated plastics. 1 page. John C. Dolph Co., Monmouth Junction, N.J.

Print No. Ins. 210 on Reader Service Card

Plastic Conduit Catalog

New catalog EC-66 of plastic conduit material for industrial, commercial and municipal power distribution presents full engineering details on the application, installation performance tests, and properties of a line of plastic conduit and fittings. 24 pages.

Carlon Products Corp., P.O. Box 133, Aurora, Ohio.
Print No. Ins. 211 on Reader Service Card

Bulletin on Machining of Laminated Plastics

Handy reference sheet lists recommended speeds and feeds for circular sawing, band sawing, turning and boring, threading, automatic screw machines, drilling, milling, gear cutting, punching, and special considerations for glass base grade of laminated plastic. Tool sizes and cutter types are listed. 24 pages. Franklin Fibre-Lamitex Corp., 129 Lafayette St., New York 13.
Print No. Ins. 212 on Reader Service Card

Radiation News

New monthly newsletter, "Radiation Review," will be directed to users of high voltage particle accelerators for research and electron accelerators for industrial processing. It will be sent without charge on request. Dept. RR-1, Radiation Dynamics Inc., Westbury, L.I., New York.
Print No. Ins. 213 on Reader Service Card

Catalog/Manual on Plastics, Wire and Cable, Tapes

New plastics catalog contains technical information for machining, forming, and processing plastics. Specific information on dielectric insulation, tensile strengths, hardness, deformation, moisture and water resistance, linear expansion and contraction characteristics is given. Molding methods for fiber glass filled molding powders and epoxy fluidizer coatings are described. Pressure-temperature selection charts, engineering facts, and machining and forming instructions for rods, tubes, sheets, film, shapes, gaskets, and laminated plastics are included. The catalog also carries information on antifriction coatings, insulated wire and cable, industrial electrical tapes, and aerosol sprays. 216 pages. R. S. Hughes Co. Inc., 4515 Alger St., Los Angeles 39.
Print No. Ins. 214 on Reader Service Card

Data Sheet on Line of High Voltage Metalized Ceramic Terminals

Technical data bulletin M-102 describes and lists specifications for the

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new L-series line of standard high voltage metalized ceramic terminals. The bulletin illustrates 4 basic type terminals and 26 different sizes offered. 2 pages. Metalizing Industries Inc., 338 Hudson St., Hackensack, N.J.

Print No. Ins. 215 on Reader Service Card

Catalog Sheet of Wiring Tools And Fastening Devices

New 1960 "Hi" catalog covers many electrical wiring tools and fastening devices, including plastic wire connectors, connector wrench, fish tape winder, wire strippers, and conduit straps. 8 pages. Holub Industries Inc., 403 DeKalb Ave., Sycamore, Ill.

Print No. Ins. 216 on Reader Service Card

Data Sheet on Leadout Index Insulator Coil

A new leadout index insulator coil is described in a new data sheet. The coil is manufactured without using molds. Specifications and temperature ranges of the material employed in the construction of the coil are fully described. 1 page. Tur-Bo Jet Products Co. Inc., 424 South San Gabriel Blvd., San Gabriel, Calif.

Print No. Ins. 217 on Reader Service Card

Bulletin on Black Light Inspection For Potting Non-Uniformity, Circuit Flux

Black light inspection for detecting residual flux on printed circuit boards, non-uniformity of potting compounds, fungicidal varnish and lacquer coatings, plastic particles in servo and gyro mechanisms, fluorinated hydrocarbons on wiring harnesses, invisible inks for quality control coding, etc., is described in detail in a new bulletin, catalog LGO-960. Specifications for a black light lamp are given and pricing information is listed for formulated fluores-

cent dyes and additives for various applications and the color which each fluoresces. 4 pages. Ultra-Violet Products Inc., San Gabriel, Calif.
Print No. Ins. 218 on Reader Service Card

Manual on Techniques For Mounting Tubing, Wiring, and Other Hardware

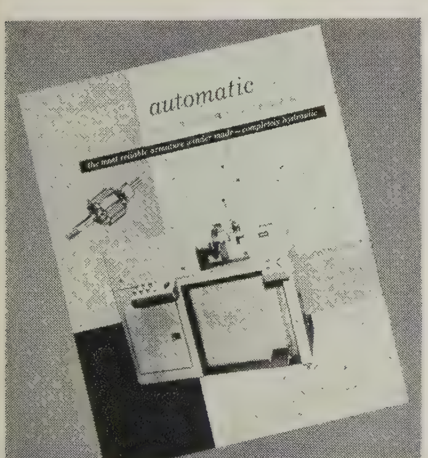
Illustrated engineering design manual (bulletin 212 G) offers a compiled listing of materials and specifications, recommended applications, and the latest technique for mounting tubing, wiring, and similar hardware. It also includes a description of a complete line of clamps, brackets, shims, and line supports for almost any application. 76 pages. TA Mfg. Co., Engineering Dept., 4607 Alger St., Los Angeles 39.
Print No. Ins. 219 on Reader Service Card

Brochure on Armature Soldering

New brochure discusses various methods utilized in the soldering of armature leads. Insulation stripping chemicals and fluxes formulated to provide faster, more economical, and efficient stripping of armature leads are listed. 5 pages. London Chemical Co., Inc., 1535 N. 31st Ave., Melrose Park, Ill.
Print No. Ins. 220 on Reader Service Card

Bulletin on Automatic Armature Winder

New illustrated bulletin 605-AL describes a new automatic armature winder (with automatic commutator hook-up feature). Complete informa-



tion on winding speed, flexibility features, and details of operating cost savings are given. Possis Machine Corp., 825 Rhode Island Ave., Minneapolis 26, Minn.
Print No. Ins. 221 on Reader Service Card

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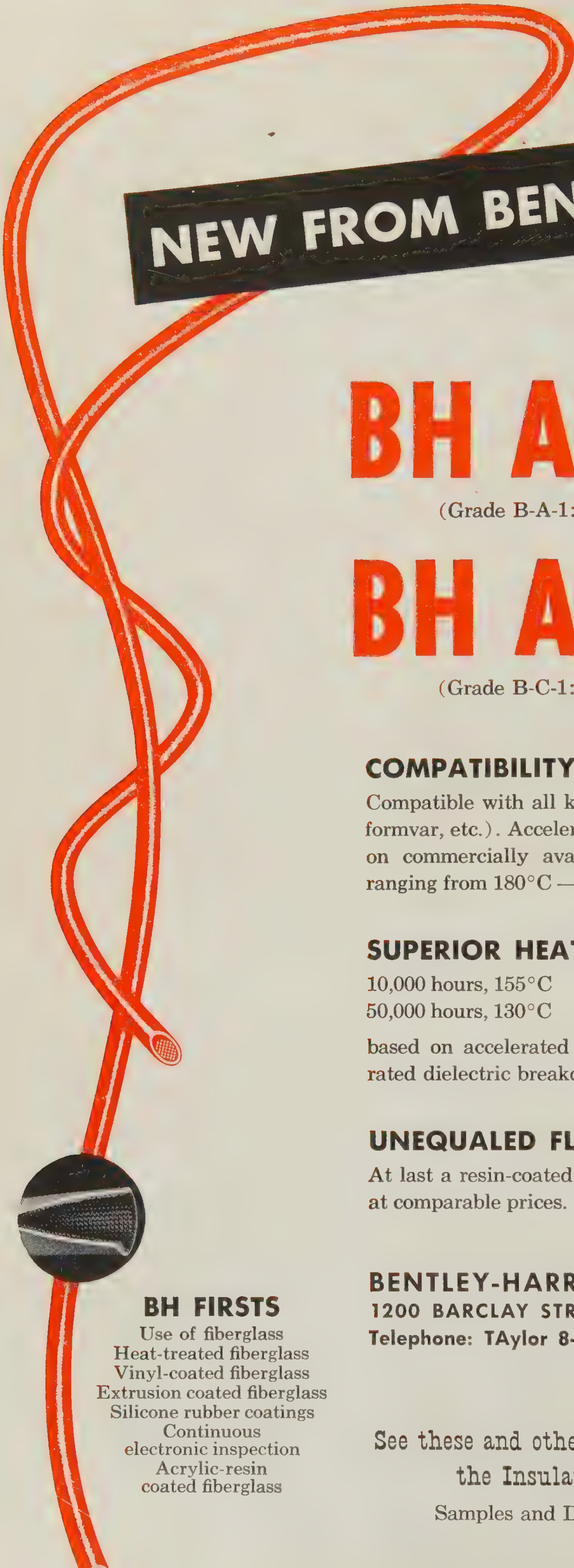

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BH ACRYL-A

(Grade B-A-1::7000 volts minimum average)

BH ACRYL-C

(Grade B-C-1::2500 volts minimum average)

COMPATIBILITY UNLIMITED

Compatible with all known wire enamels (polyester, epoxy, formvar, etc.). Accelerated heat aging has disclosed no effect on commercially available magnet wire at temperatures ranging from 180°C — 280°C.

SUPERIOR HEAT LIFE

10,000 hours, 155°C
50,000 hours, 130°C

based on accelerated heat aging tests — end point: ½ of rated dielectric breakdown (ASTM D350)

UNEQUALED FLEXIBILITY

At last a resin-coated sleeving as flexible as Vinyl-glass and at comparable prices.

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Vinyl-coated fiberglass
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